ICHEP PARIS 2010

Measurements of the CKM angle γ at BaBar

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On behalf of the BaBar Collaboration

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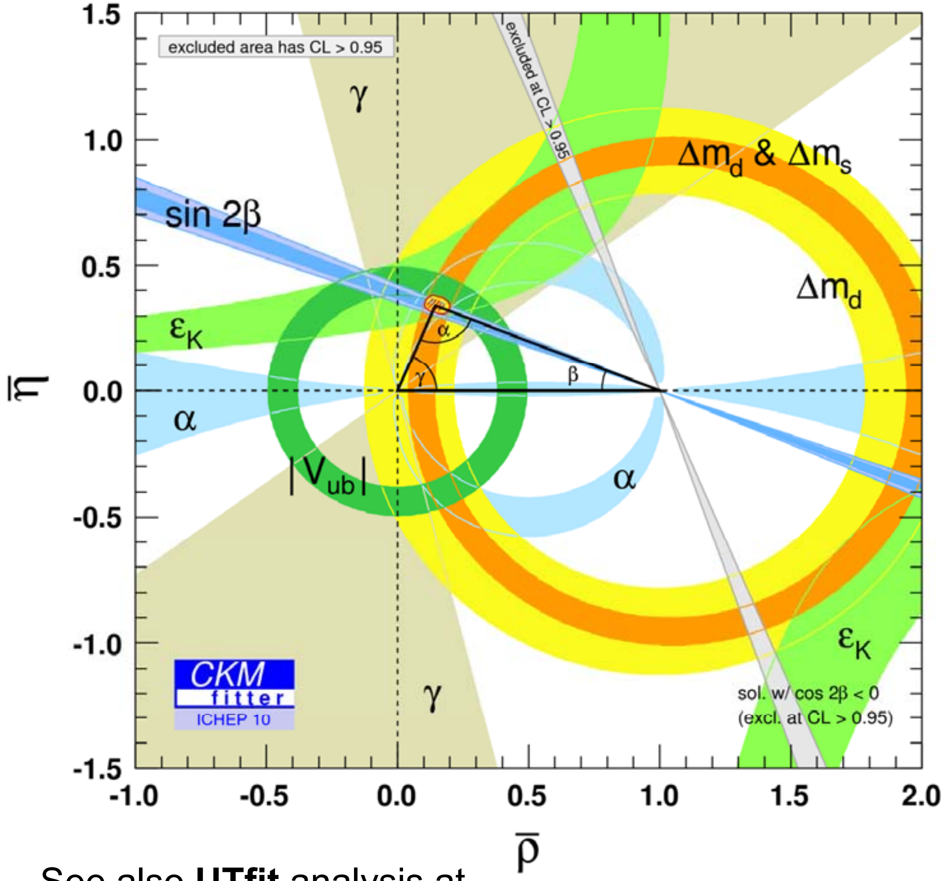
CSIC

CKM angle γ



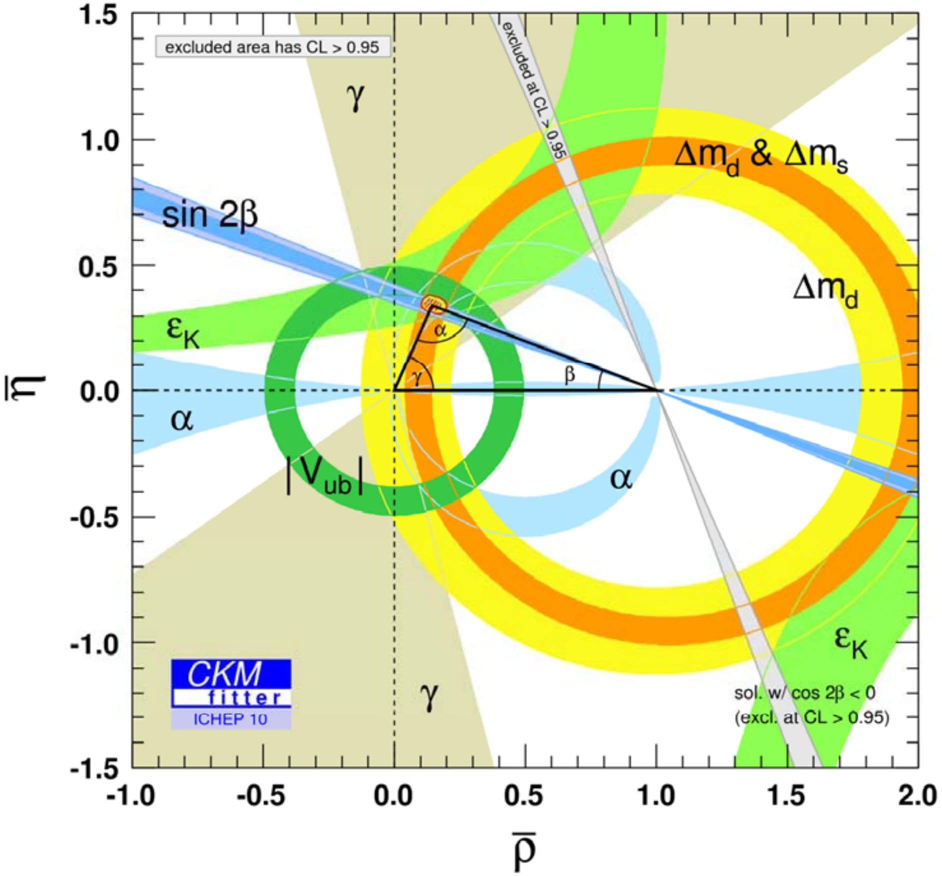
See also **UTfit** analysis at http://www.utfit.org/

Very impressive consistency

Kobayashi and Maskawa awarded half of 2008 N.P.

- Apex of the CKM Unitary Triangle (UT) over constrained
  - CP violation measurements give angles
  - Semileptonic decay rates (and other methods) give sides
- Precise measurement of SM parameters
- Search for NP in discrepancies of redundant measurements
- Still have some work to do on γ: less precisely known UT angle (most difficult to measure)

CKM angle γ



Experiments providing most of analyses today

This talk

3.1 GeV e^+
9 GeV e^-
468M $B\bar{B}$ pairs

BELLE

3.5 GeV e^+
8 GeV e^-
657M $B\bar{B}$ pairs

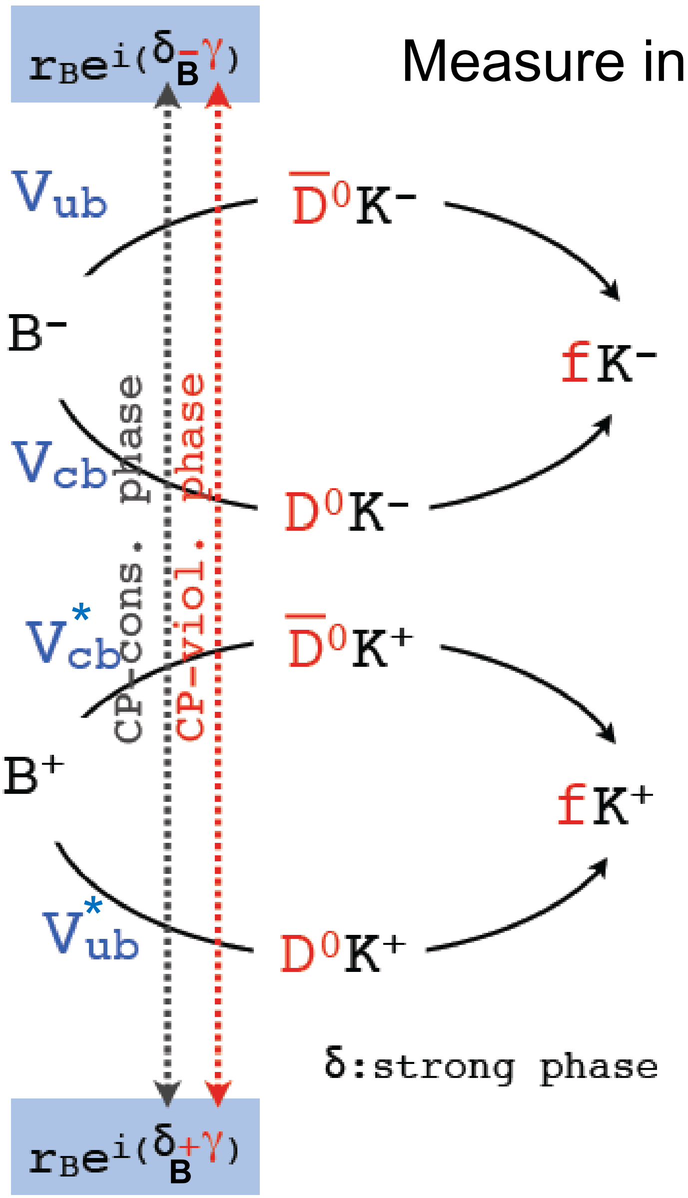
~10-15°

- Apex of the CKM Unitary Triangle (UT) over constrained
  - CP violation measurements give angles
  - Semileptonic decay rates (and other methods) give sides
- Precise measurement of SM parameters
- Search for NP in discrepancies of redundant measurements
- Still have some work to do on γ: less precisely known UT angle (most difficult to measure)
- Important to measure γ since, together with $|V_{ub}|$, selects ρ-η value independently of most types of NP

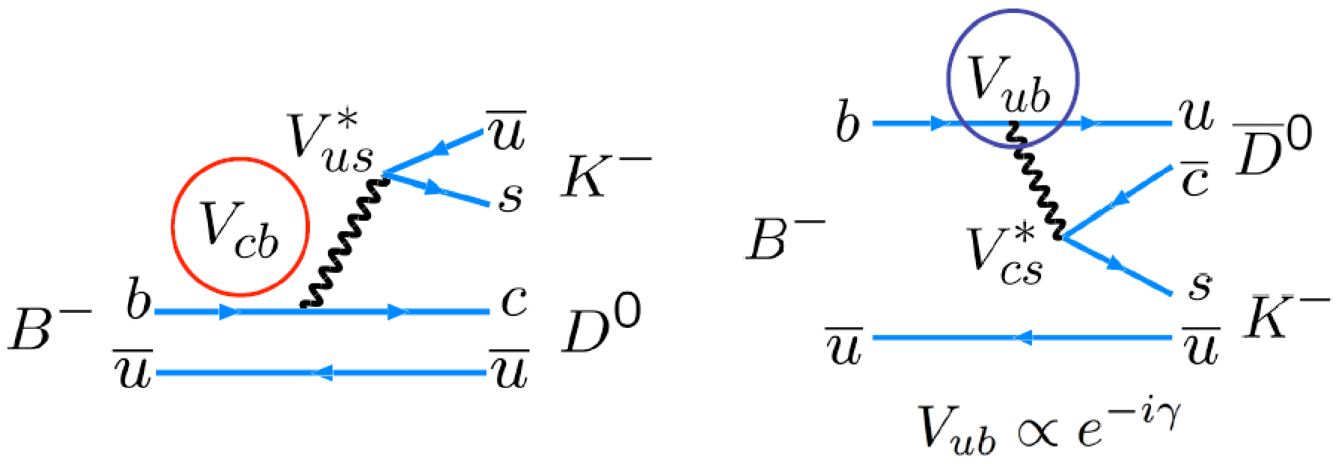
  ⇒ SM candle type of measurement

- The constraint on γ come from tree-level $B \to DK$ decays

γ from B→DK decays



Measure interference between tree amplitudes b→u and b→c

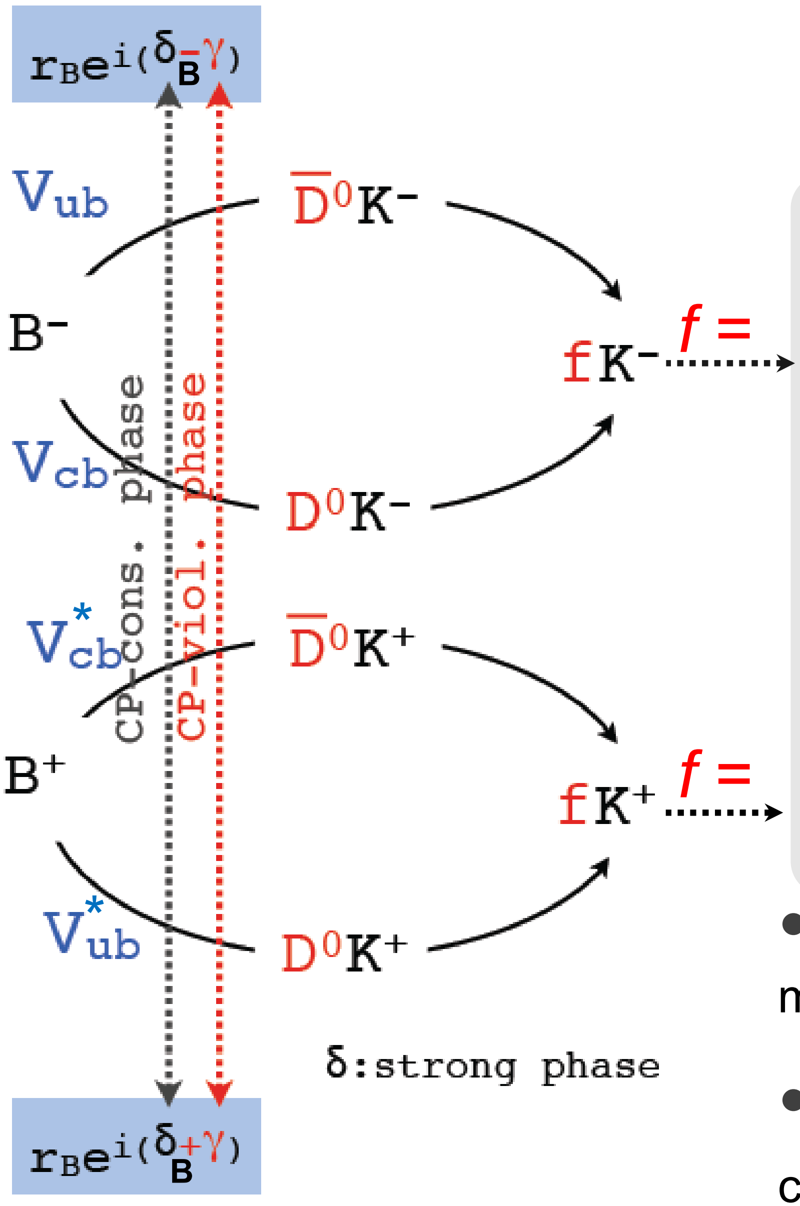


- Use final state accessible from both D^0 and $\bar{D}^0$
- Largely unaffected by New Physics

- Clear theoretical interpretation of observables in terms of γ
- Difficult because BFs are small due to CKM suppresion (10^{-5}-10^{-7}, so not many events) and $r_B = |A_{ub}|/|A_{cb}|$ is small due to further CKM and color suppressions (small interference)

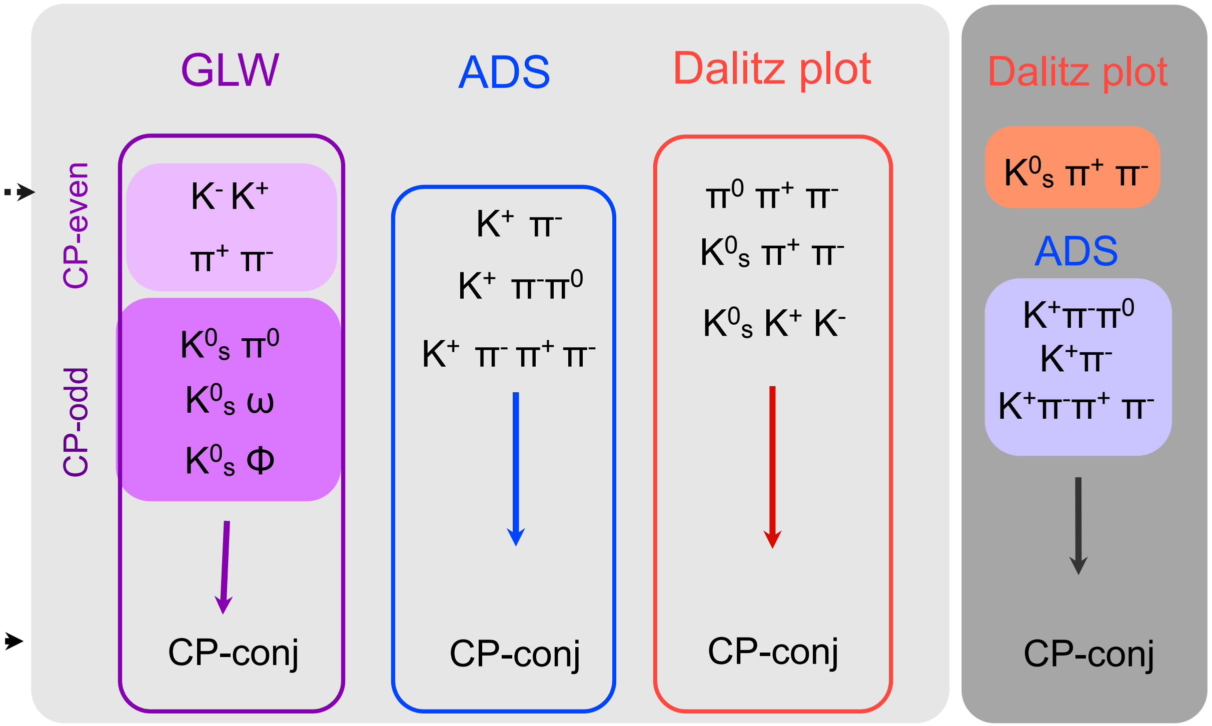
⇒ All measurements are statistics limited

γ from B→DK decays



Charged $B \to D^{(*)0} K^{(*)}$ $r_B \sim 0.1$

Neutral $B \to D^{(*)0} K^{*0}$ $r_B \sim 0.3$



- Complementary methods applied on same B decay modes share the same hadronic parameters (r_B, δ_B) and γ
- <u>Strategy</u>: many decay chains are analyzed and then combined to improve the overall sensitivity to γ
- *In this talk* we present  or recent results

Atwood, Dunietz, Soni, PRL 78, 3357 (1997)
Gronau, London, Wyler, PLB 253, 483 (1991); PLB 265, 172 (1991)

γ from B→DK decays

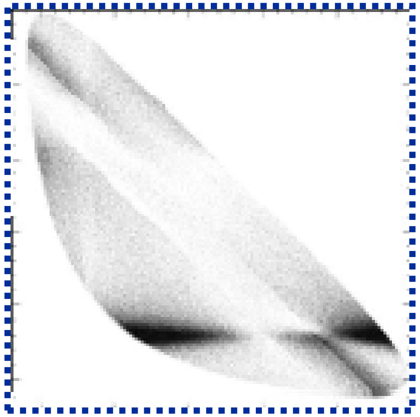
Dalitz plot method

$s_{\mp} \equiv m^2(K_S\pi^{\mp})$

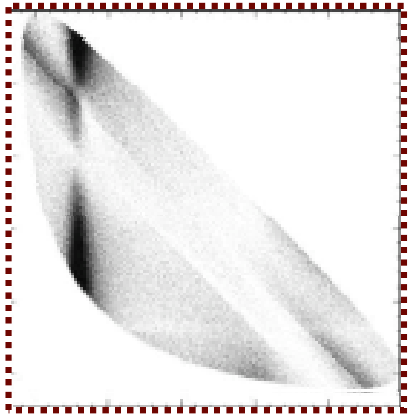
No D-mixing nor CPV

Decay amplitude

$A(B^- \to [K_S\pi^+\pi^-]K^-) \propto$ ($D^0 \to K_S\pi^+\pi^-$ $+ r_B e^{-i\gamma+i\delta_B}$ $\overline{D}^0 \to K_S\pi^+\pi^-$)



b→c

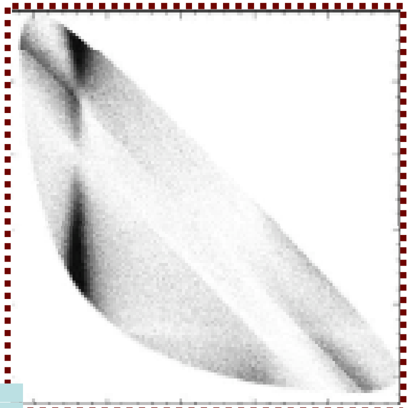


b→u

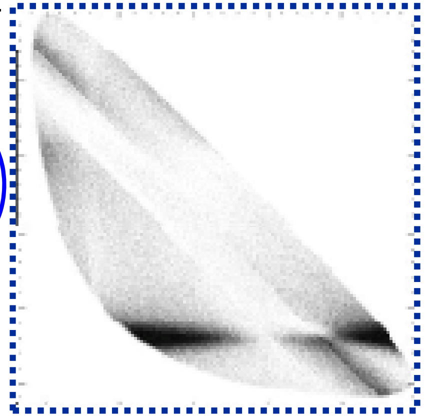
Hadronic parameters

- D^0 decay strong phase variation
- Hadronic parameters
- r_B=|A(b→u)|/|A(b→c)|
- δ_B (strong phase difference between A(b→u) and A(b→c))
- determined experimentally from data

$A(B^+ \to [K_S\pi^+\pi^-]K^+) \propto$ ($\overline{D}^0 \to K_S\pi^+\pi^-$ $+ r_B e^{+i\gamma+i\delta_B}$ $D^0 \to K_S\pi^+\pi^-$)



$\overline{b} \to \overline{c}$



$\overline{b} \to \overline{u}$

Giri, Grossman, Soffer, Zupan, PRD 68, 054018 (2003);

Bondar, unpublished.

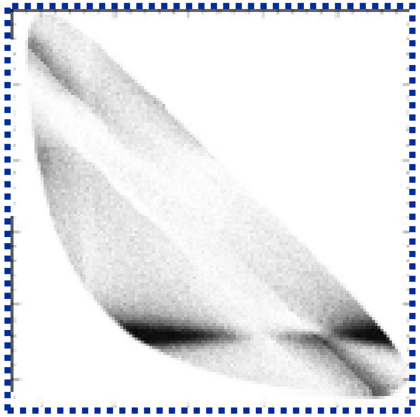
γ from B→DK decays

Dalitz plot method

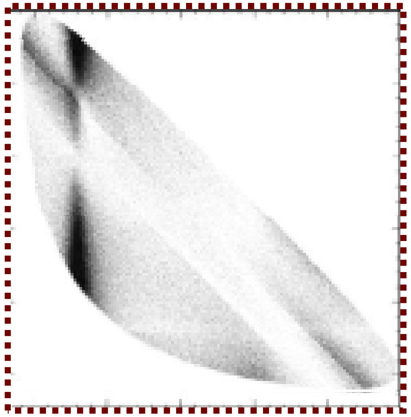
No D-mixing nor CPV

Decay amplitude

$$A(B^- \to [K_S\pi^+\pi^-]K^-) \propto \Big(\quad D^0 \to K_S\pi^+\pi^- \quad + r_B e^{-i\gamma + i\delta_B} \quad \overline{D}^0 \to K_S\pi^+\pi^- \quad \Big)$$



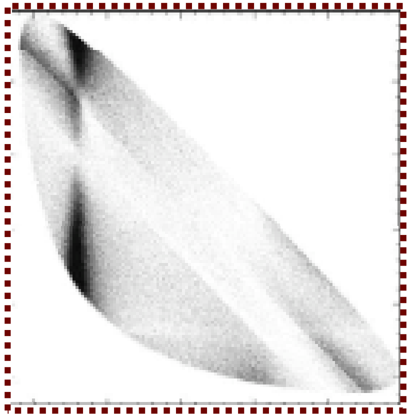
b→c



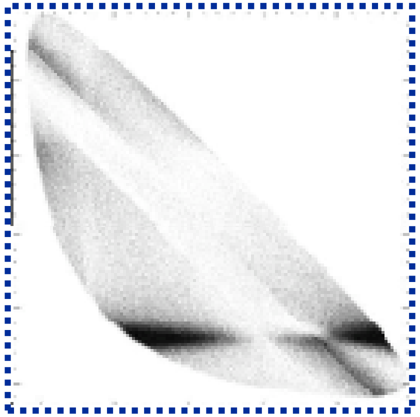
b→u

Relative weak phase γ changes sign

$$A(B^+ \to [K_S\pi^+\pi^-]K^+) \propto \Big(\quad \overline{D}^0 \to K_S\pi^+\pi^- \quad + r_B e^{+i\gamma + i\delta_B} \quad D^0 \to K_S\pi^+\pi^- \quad \Big)$$



$\overline{b}$→$\overline{c}$



$\overline{b}$→$\overline{u}$

Interference terms in decay rates proportional to

$$x_\mp = r_B \cos(\delta_B \mp \gamma)$$

$$y_\mp = r_B \sin(\delta_B \mp \gamma)$$

Fit for $x_\pm$ and $y_\pm$ for each B decay mode

γ from B→DK decays

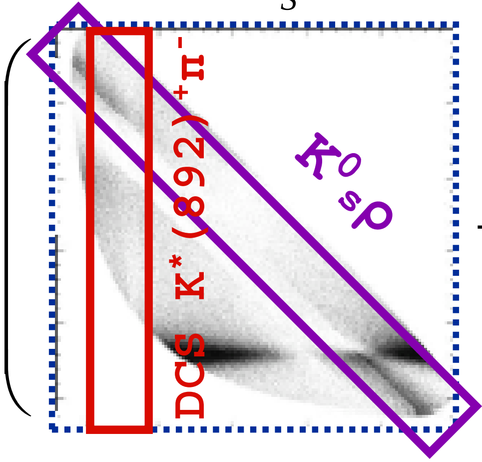
Dalitz plot method

No D-mixing nor CPV

Decay amplitude

$$A(B^- \to [K_S\pi^+\pi^-]K^-) \propto$$

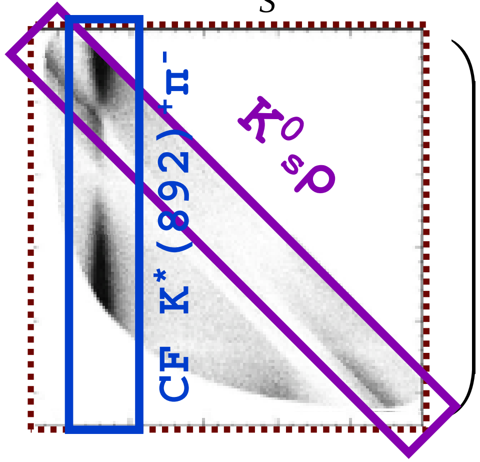
$D^0 \to K_S\pi^+\pi^-$



b→c

$$+ r_B e^{-i\gamma+i\delta_B}$$

$\overline{D}^0 \to K_S\pi^+\pi^-$



b→u

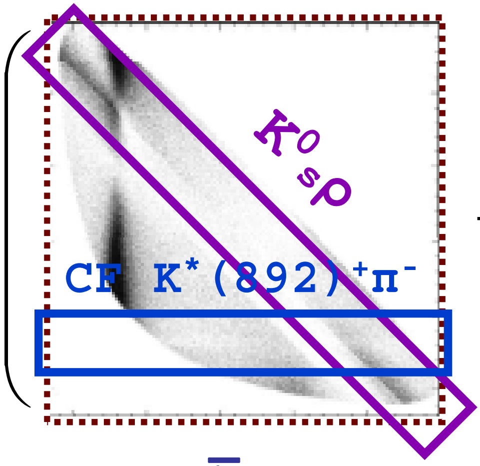
Large interference in some regions of the Dalitz plot, e.g.

$D^0 \to K_S\rho$

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

$$A(B^+ \to [K_S\pi^+\pi^-]K^+) \propto$$

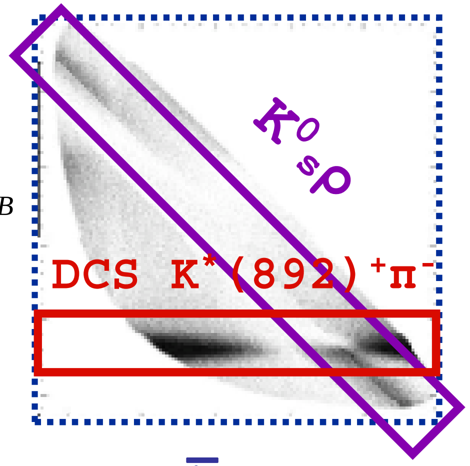
$\overline{D}^0 \to K_S\pi^+\pi^-$



$\bar{b} \to \bar{c}$

$$+ r_B e^{+i\gamma+i\delta_B}$$

$D^0 \to K_S\pi^+\pi^-$



$\bar{b} \to \bar{u}$

Experimental techniques

- Exclusive reconstruction of multiple B decays:

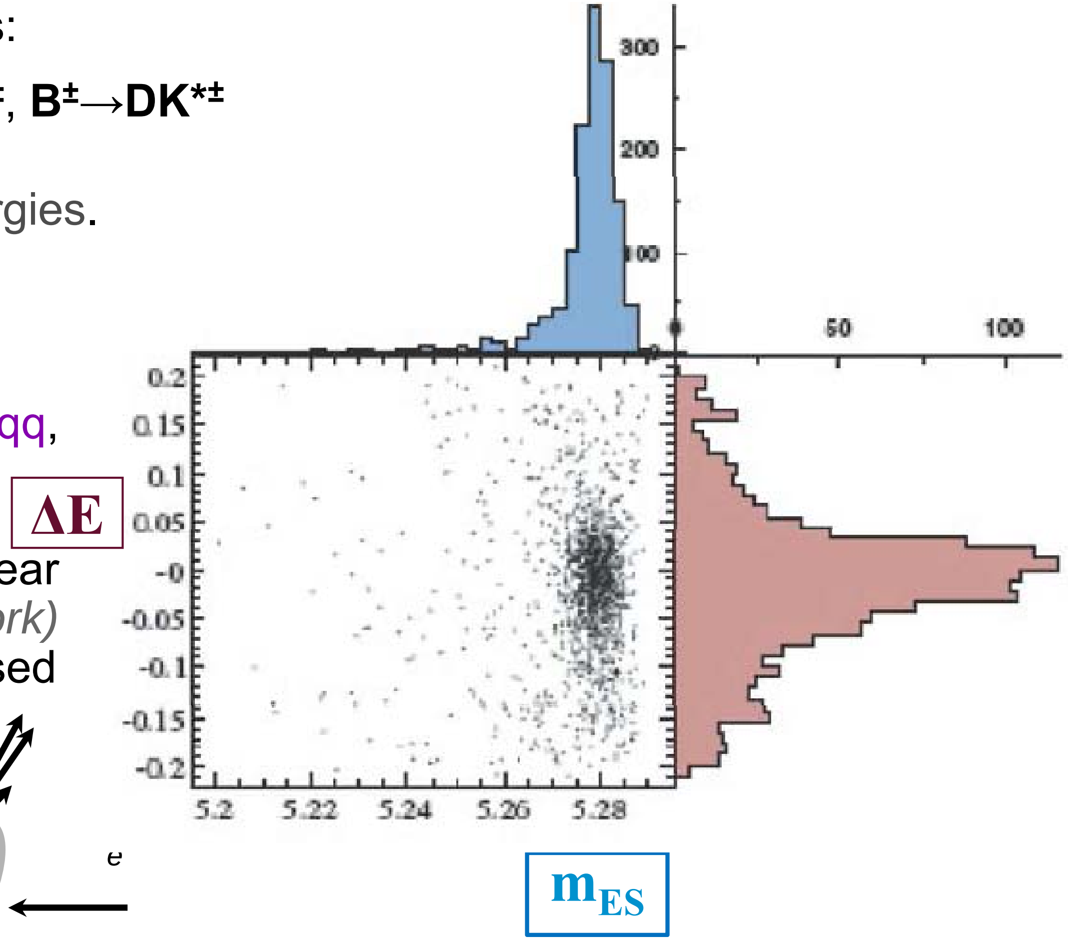
  $B^{\pm}\to DK^{\pm}$, $B^{\pm}\to D^{*}[D\pi^{0}]K^{\pm}$, $B^{\pm}\to D^{*}[D\gamma]K^{\pm}$, $B^{\pm}\to DK^{*\pm}$

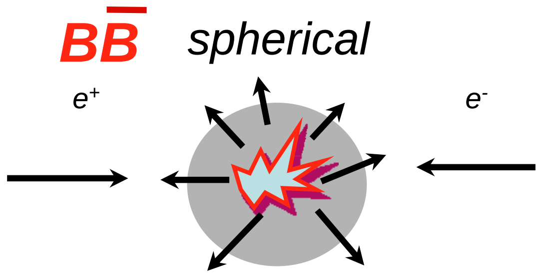
- Exploit kinematic constraints from beam energies.

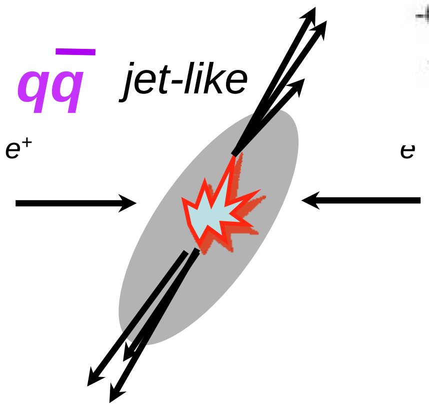
  $m_{ES}=\sqrt{E^{*2}_{beam}-|p_B^*|^2}$ $\Delta E=E_B^*-E^*_{beam}$

- The main source of background : $e^+e^-\to q\bar{q}$, with q=u,d,s,c

- Event shape variables combined into a linear *(Fisher)* or non linear *(Neural Network)* combination. Tagging information sometimes used







- Signal is separated from background through unbinned maximum likelihood fits to $B^{\pm}\to D^{(*)}K^{(*)\pm}$ data using m_{ES}, ΔE and *Fisher* (or *Neural Network)* discriminant

- Use large $B^{\pm}\to D^{(*)}\pi^{\pm}$ data control samples (r_B~0.01, x10 smaller than for DK)

γ from D Dalitz plot method

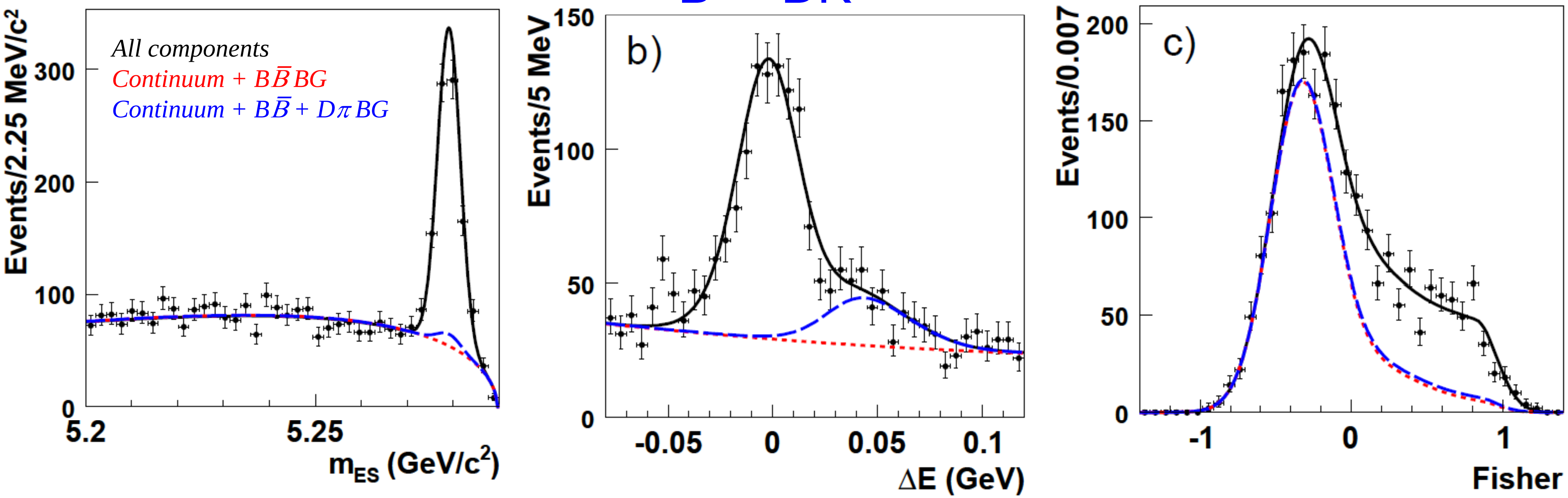
- BaBar analysis based on complete data sample (468 M $B\bar{B}$ pairs)

arXiv:1005.1096.
Sub. to Phys. Rev. Lett.

- Reconstruct **$B^{\pm}\to DK^{\pm}$, $B^{\pm}\to D^{*}[D\pi^{0}]K^{\pm}$, $B^{\pm}\to D^{*}[D\gamma]K^{\pm}$**, and **$B^{\pm}\to DK^{*\pm}$** final states with **$D\to K_S\pi^+\pi^-$, $K_SK^+K^-$** (eight different final states for each B charge)

Only BaBar

$B^{\pm}\to DK^{\pm}$



- Efficiencies improved substantially (20% to 40% relative) with respect to previous BaBar measurement (383 M $B\bar{B}$) PRD78, 034023 (2008)
  - Reprocessed data set with improved track reconstruction
  - Improved particle identification
  - Revised K_S selection criteria: negligible background from $D\to\pi^+\pi^-h^+h^-$ and $B\to Da_1(1260)$

$D \to K_S\pi^+\pi^-, K_S K^+K^-$ amplitude analysis

arXiv:1004.5053. Accepted by Phys. Rev. Lett.

- Extract D^0 amplitude from an independent analysis of flavor tagged D^0 mesons ($D^{*+} \to D^0\pi^+$)
- Experimental analysis using complete data sample benefits from synergy with D-mixing analysis
  - ➡ Model determined without (reference) and with D-mixing

See Matt Bellis talk in this session for more details

- Fit for amplitudes relative to CP eigenstates [$K_S\rho(770)$ and $K_S a_0(980)$] and assume no direct CPV

Wave	Parameterization
ππ S-wave	K-matrix
Kπ S-wave	K-matrix (LASS-like)
ππ P-wave	BW: ω(782), G.S ρ(770)
Kπ P-wave	BW: CA and DCS K*(892), CA K*(1680)
ππ D-wave	BW $f_2(1270)^0$
Kπ D-wave	BW CA and DCS K_2*(1430)

Main differences with Belle

Wave	Parameterization
$K^\pm K_S$ S-wave	BW: CA and DCS $a_0(980)$, CA $a_0(1450)$
K^+K^- S-wave	Flatte a_0 (980), BW $a_0(1450)$ and f0(1370)
K^+K^- P-wave	BW Φ(1020)
K^+K^- D-wave	BW $f_2(1270)^0$

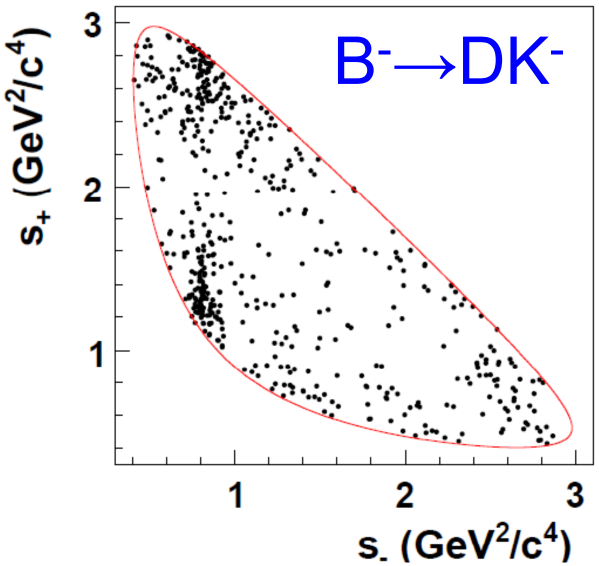
Good fit quality (χ^2/ndof) taking into account statistical, experimental and model uncertainties

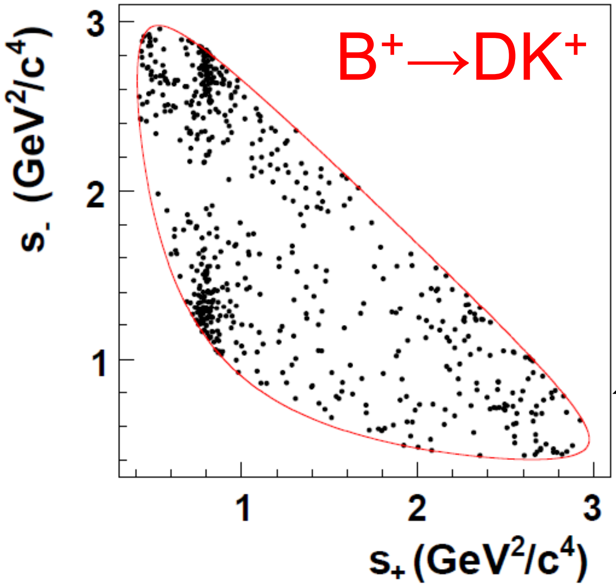
γ from D Dalitz plot method

NEW!

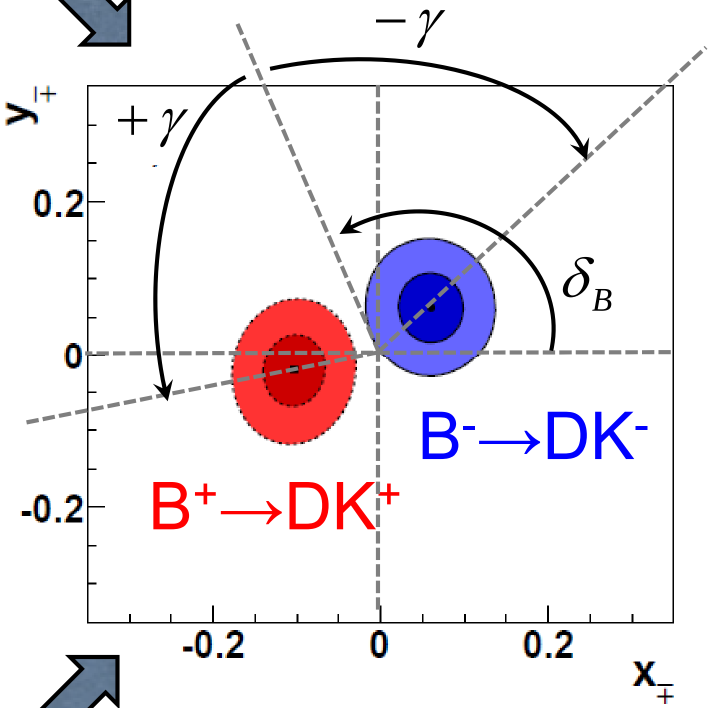
- CP violation parameters are extracted from simultaneous unbinned maximum likelihood fit to $B^\pm \to D^{(*)} K^{(*)\pm}$ data using m_{ES}, ΔE, *Fisher* and the Dalitz plot distributions (s+,s-)

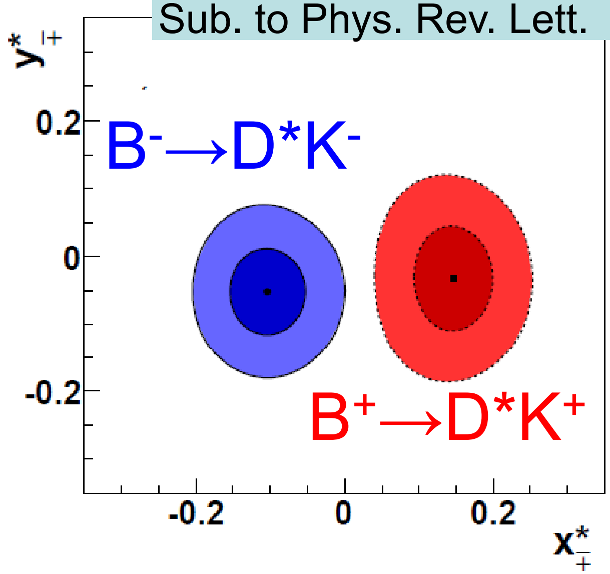
arXiv:1005.1096.
Sub. to Phys. Rev. Lett.

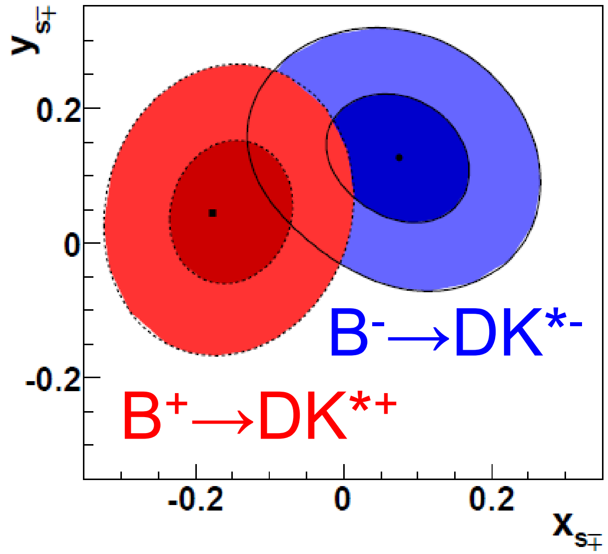




$$x_\mp = r_B \cos(\delta_B \mp \gamma)$$
$$y_\mp = r_B \sin(\delta_B \mp \gamma)$$





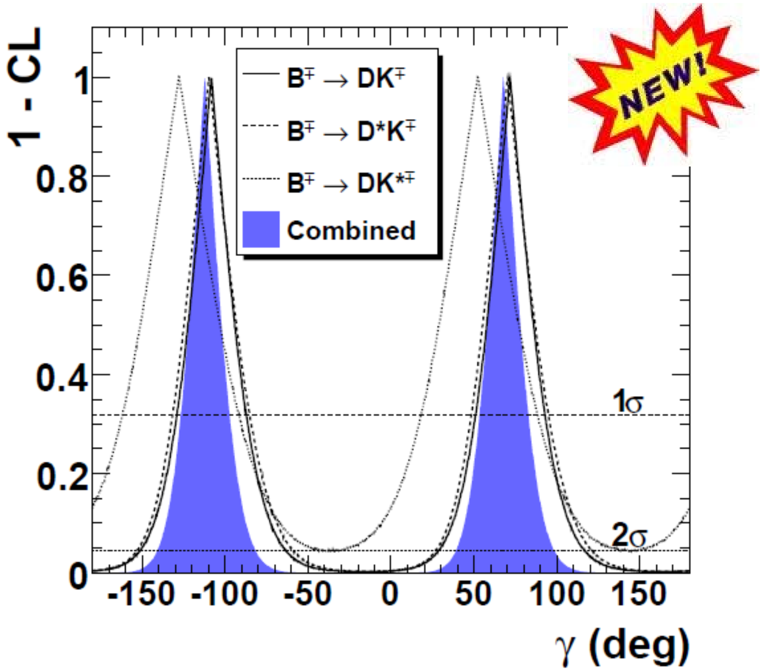


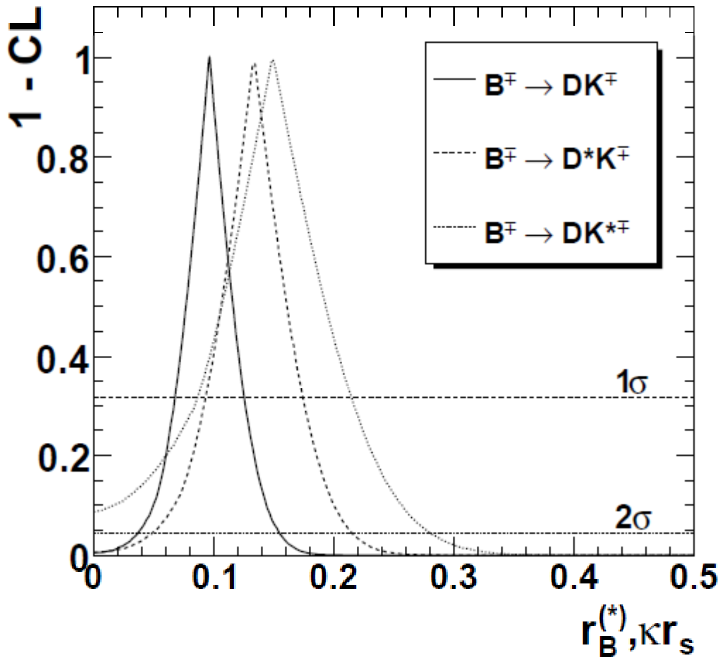
Differences between B+ and B- gives information on γ

γ from D Dalitz plot method

- Use frequentist method to obtain the (common) weak phase γ and the hadronic parameters r_B, δ_B (different for each B decay channel) from 12 (x,y) observables

arXiv:1005.1096.
Sub. to Phys. Rev. Lett.





$$r_B(DK) = 0.096 \pm 0.029$$
$$r_B^*(D^*K) = 0.133^{+0.042}_{-0.039}$$
$$\chi r_S(DK^*) = 0.149^{+0.066}_{-0.062}$$

$$\delta_B(DK) = (119^{+19}_{-20})^\circ$$
$$\delta_B^*(D^*K) = (-82 \pm 21)^\circ$$
$$\delta_S(DK^*) = (111 \pm 32)^\circ$$

$$\gamma \text{ (mod } 180^\circ) = (68 \pm 14 \pm 4 \pm 3)^\circ$$
stat syst model

3.5σ significance of CPV

Our previous result:
$$\gamma \text{ (mod } 180^\circ) = (76 \pm 22 \pm 5 \pm 5)^\circ$$

[Error on γ scales roughly as $1/r_B$]

- Smaller stat error due to additional data + improved reconstruction + slightly higher $r_B(DK)$
- Model error benefited from overlap with D-mixing analysis (e.g. reduction of experimental uncertainties inherent to the model uncertainty)

$$\gamma \text{ (mod } 180^\circ) = (78.4\ ^{+10.8}_{-11.6} \pm 3.6 \pm 8.9)^\circ \quad r_B(DK) = 0.160^{+0.040}_{-0.038}$$

BELLE

γ from ADS method

arXiv:1006.4241. Sub. to Phys. Rev. D

NEW!

- Update with final data sample (468 M $B\bar{B}$ pairs). Previous analysis used 232 M $B\bar{B}$ pairs PRD72, 032004 (2005)

- Reconstruct **B±→DK±**, **B±→D* [Dπ⁰]K±** , and **B±→D* [Dγ]K±**, with
  - **D→K±π∓ ("same sign")**
  - **D→K∓π± ("opposite sign")**

"opposite sign"

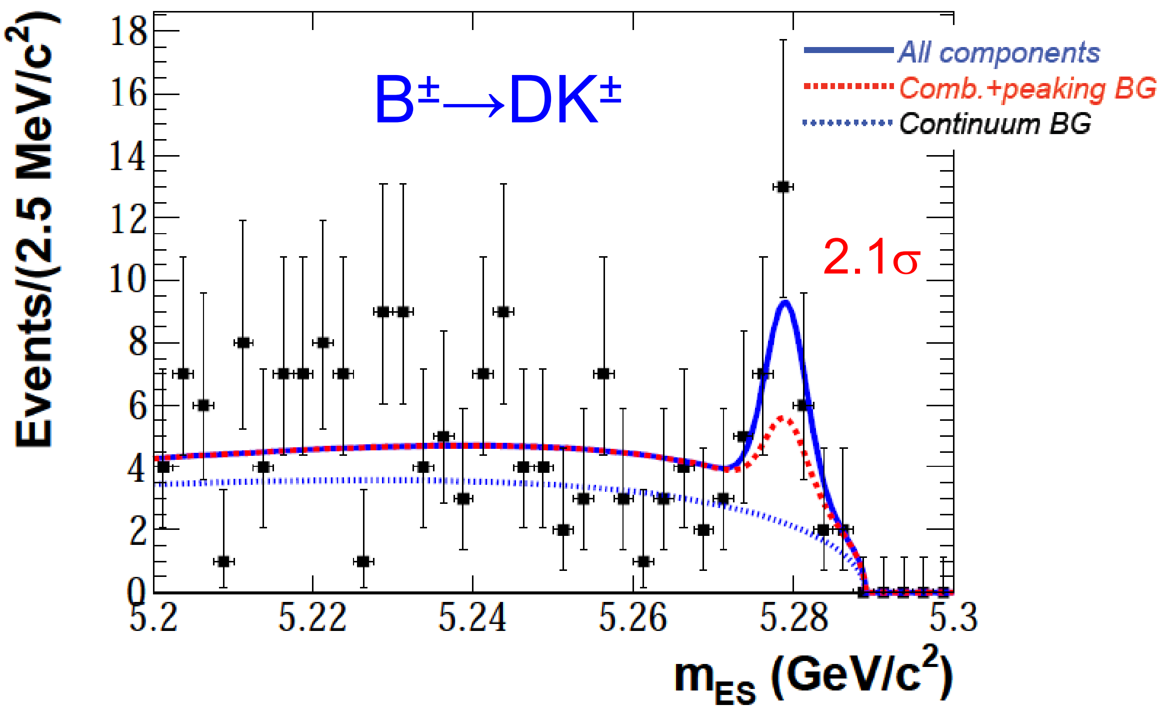
$B^- \to D^0 K^-$ favored $(b \to c)$ followed by $D^0 \to K^+\pi^-$ suppressed $(c \to d)$

interferes with

$B^- \to \bar{D}^0 K^-$ suppressed $(b \to u)$ followed by $\bar{D}^0 \to K^+\pi^-$ favored $(\bar{c} \to \bar{s})$

"Maximizes" CP asymmetry since "equalizes" the magnitudes of the interfering amplitudes

First sign of an ADS signal in
B± → DK± (2.1σ)
and
B± → D* K± (2.2σ)



γ from ADS method

arXiv:1006.4241.
Sub. to Phys. Rev. D

- Fit directly observables R_{ADS} and B± "same sign" yields $\Gamma(B^{\pm} \to [K^{\pm}\pi^{\mp}]_D K^{\pm})$ to reconstruct the ADS asymmetry

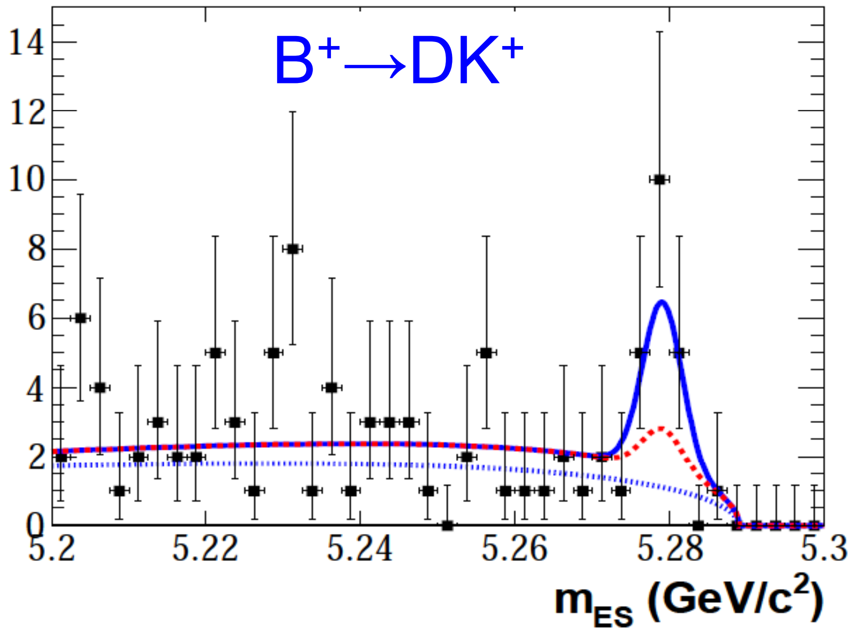
NEW!

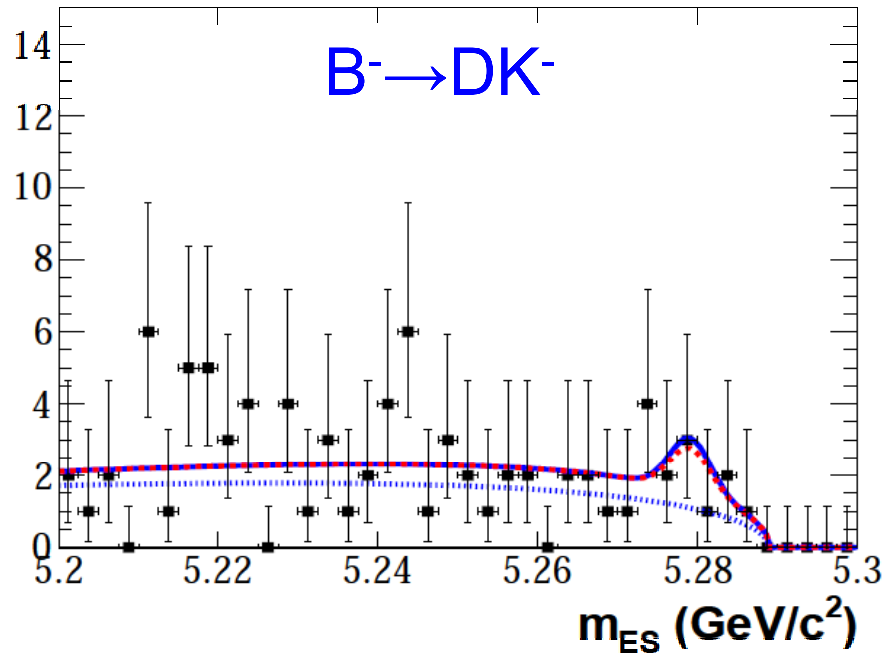
Good sensitivity to r_B

$$R_{ADS} = \frac{1}{2}(R^{+} + R^{-}) = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D)\cos\gamma$$

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

$$R^{\pm} = \frac{\Gamma(B^{\pm} \to [K^{\mp}\pi^{\pm}]_D K^{\pm})}{\Gamma(B^{\pm} \to [K^{\pm}\pi^{\mp}]_D K^{\pm})}$$





$$R_{ADS}(DK) = 0.011 \pm 0.006 \pm 0.002$$

$$R^{*}_{ADS}([D\pi^{0}]K) = 0.018 \pm 0.009 \pm 0.004$$

$$R^{*}_{ADS}([D\gamma]K) = 0.013 \pm 0.014 \pm 0.008$$

$$A_{ADS}(DK) = -0.86 \pm 0.47^{+0.12}_{-0.16}$$

$$A^{*}_{ADS}([D\pi^{0}]K) = 0.77 \pm 0.35 \pm 0.12$$

$$A^{*}_{ADS}([D\gamma]K) = 0.36 \pm 0.94^{+0.25}_{-0.41}$$

γ from ADS method

arXiv:1006.4241.
Sub. to Phys. Rev. D

- Use frequentist interpretation (similar to Dalitz plot method) to obtain weak phase γ and hadronic parameters r_B, δ_B from $R_{ADS}^{(*)}$ and $A_{ADS}^{(*)}$ observables

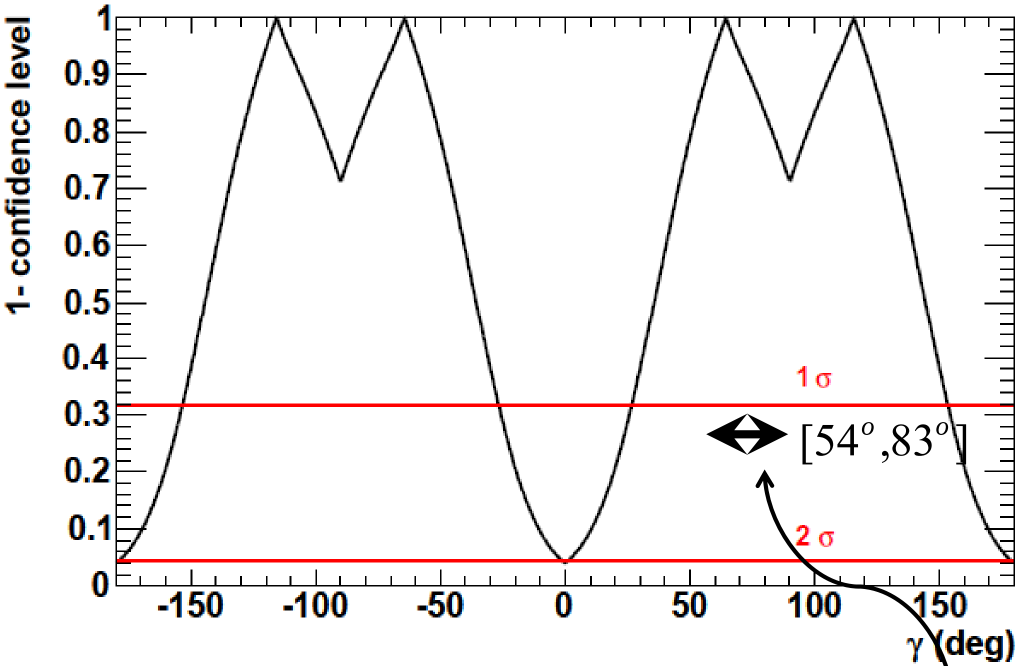
Inputs:

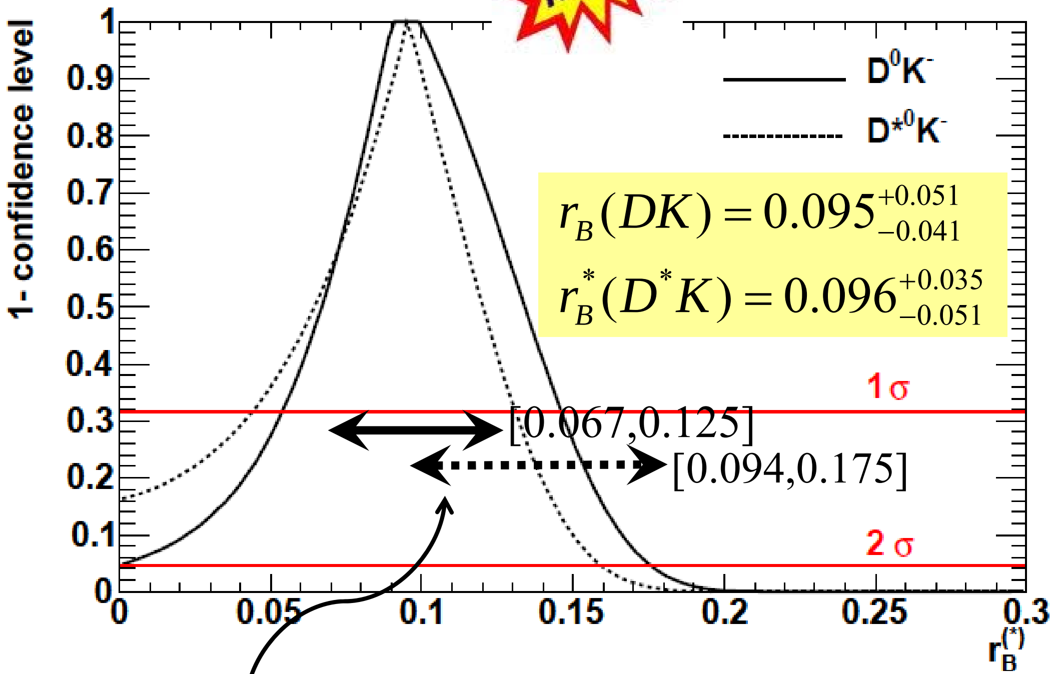
$$r_D = \frac{|A(\bar{D}^0 \to K^-\pi^+)|}{|A(D^0 \to K^-\pi^+)|} \quad \text{(HFAG)}$$

$$\delta_D = \arg\left[\frac{A(\bar{D}^0 \to K^-\pi^+)}{A(D^0 \to K^-\pi^+)}\right] \quad \text{(CLEOc)}$$

$r_D = (5.78 \pm 0.08)\%$ $\delta_D = (201.9 {}^{+11.4}_{-12.4})^o$
(HFAG, CLEOc)

NEW!





BaBar Dalitz plot method

γ from GLW method

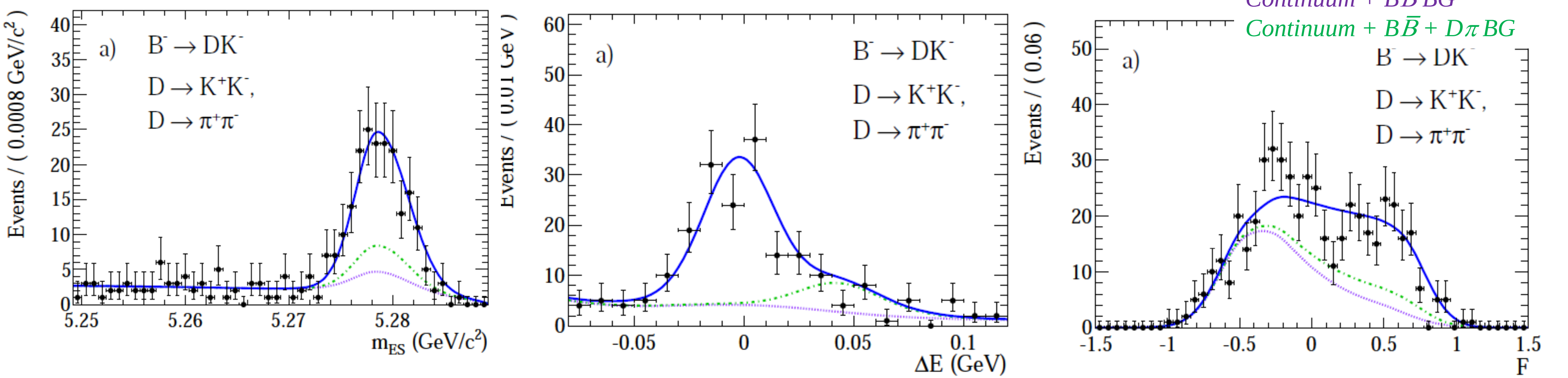
arXiv:1007.0504.
Sub. to Phys. Rev. D

- Update with final data sample (468 M $B\bar{B}$ pairs). Previous analysis used 383 M $B\bar{B}$ pairs

PRD77, 111102 (2008)

- Reconstruct **$B^{\pm}\to DK^{\pm}$** final states with **$D\to K^+K^-,\pi^+\pi^-$** (CP even) and **$D\to K_S\pi^0, K_S\omega, K_S\phi$** (CP odd) (five different final states for each B charge)

$B^-\to DK^-$



- Efficiencies improved substantially (40% to 60% relative) with respect to previous measurement
  - Reprocessed data set with improved track reconstruction
  - Improved particle identification
  - Introduce Fisher discriminant in the fit rather than apply cut on event shape variables

γ from GLW method

arXiv:1007.0504.
Sub. to Phys. Rev. D

- Extract signal yields fitting directly to observables $R^{\pm}_{K/\pi}$, $R_{K/\pi}$, and $A_{CP\pm}$

$$R^{\pm}_{K/\pi} = \frac{\Gamma(B^- \to D_{CP\pm}K^-) + \Gamma(B^+ \to D_{CP\pm}K^+)}{\Gamma(B^- \to D_{CP\pm}\pi^-) + \Gamma(B^+ \to D_{CP\pm}\pi^+)}$$

$$R_{K/\pi} = \frac{\Gamma(B^- \to D^0 K^-) + \Gamma(B^+ \to \overline{D}^0 K^+)}{\Gamma(B^- \to D^0 \pi^-) + \Gamma(B^+ \to \overline{D}^0 \pi^+)}$$

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$$R_{CP\pm} \approx \frac{R^{\pm}_{K/\pi}}{R_{K/\pi}}$$

3.6σ significance of CPV in $B^{\pm} \to DK^{\pm}$ from A_{CP+}

$$A_{CP+} = 0.25 \pm 0.06 \pm 0.02$$

$$A_{CP-} = 0.09 \pm 0.07 \pm 0.02$$

$$R_{CP+} = 1.18 \pm 0.09 \pm 0.05$$

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γ from GLW method

arXiv:1007.0504.
Sub. to Phys. Rev. D

NEW!

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$$x_{\pm} = \frac{1}{4}\left[R_{CP+}(1 \mp A_{CP+}) - R_{CP-}(1 \mp A_{CP-})\right]$$

$$x_+ = -0.057 \pm 0.039 \pm 0.015$$

$$x_- = +0.132 \pm 0.042 \pm 0.018$$

Consistent with and of similar precision to Dalitz results

$$x_+ = -0.103 \pm 0.037 \pm 0.006 \pm 0.007$$

$$x_- = +0.060 \pm 0.039 \pm 0.007 \pm 0.006$$

[Dalitz results]

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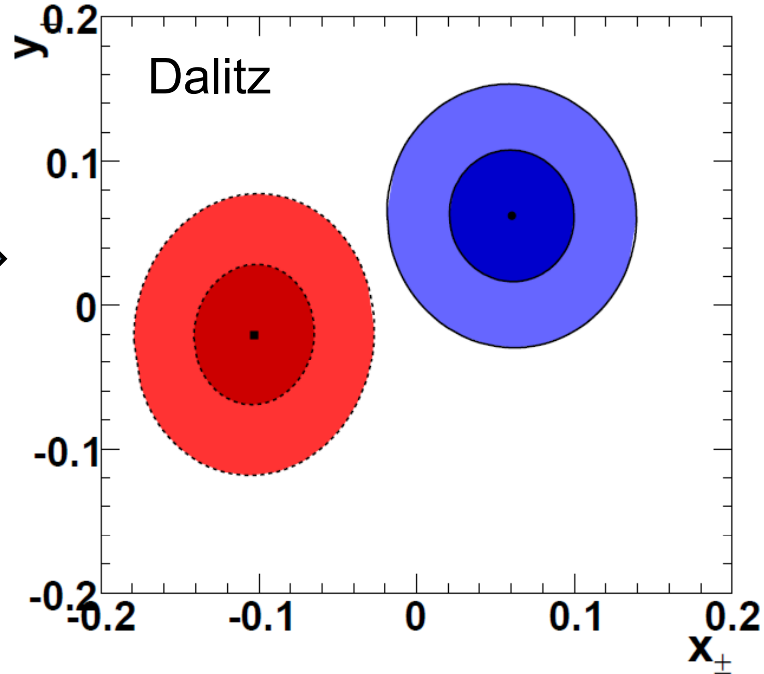

$$x_- - x_+(\text{Dalitz}) = 0.163 \pm 0.055 \quad (3.0\sigma)$$

$$x_- - x_+(\text{GLW}) = 0.189 \pm 0.062 \quad (3.1\sigma)$$

γ from GLW method

arXiv:1007.0504.
Sub. to Phys. Rev. D

NEW!

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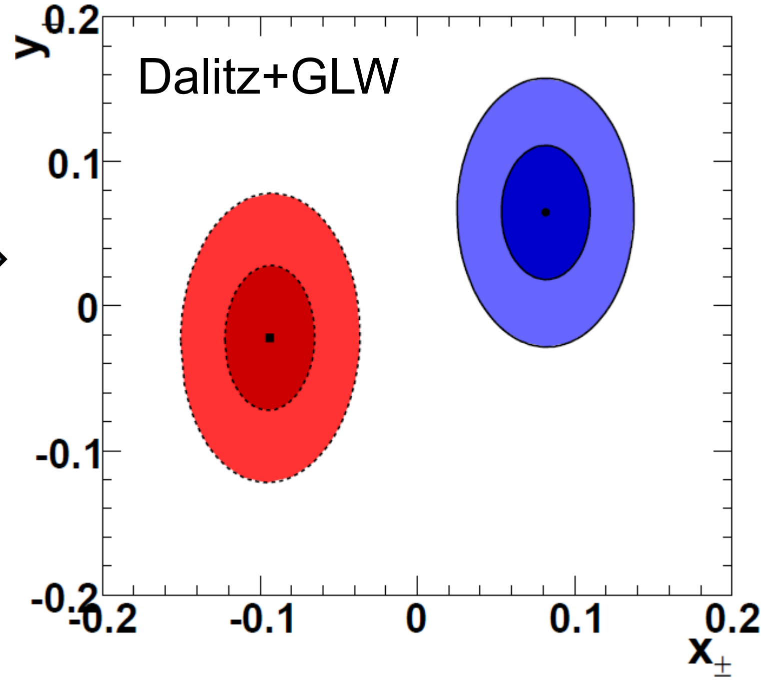


4.4σ significance of CPV in B±→DK±

$$x_- - x_+ (\text{Dalitz} + \text{GLW}) = 0.175 \pm 0.040$$

γ from GLW method

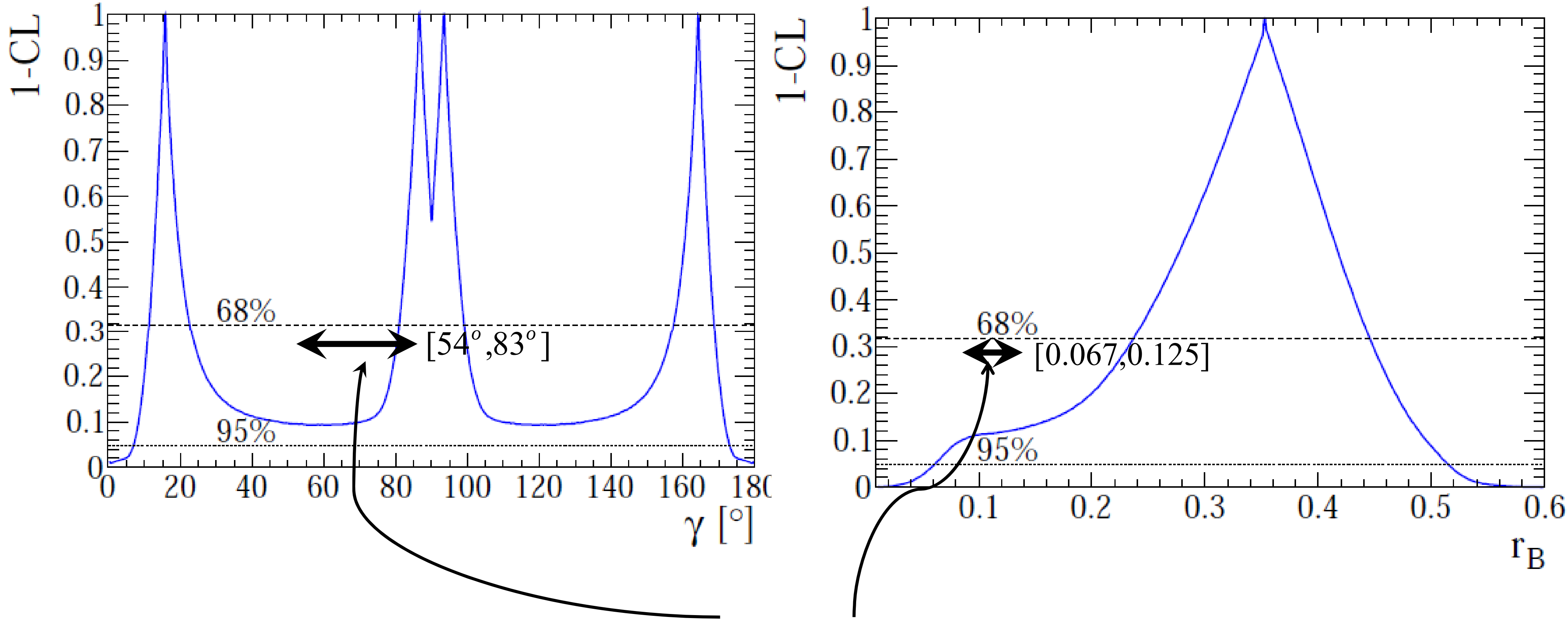
arXiv:1007.0504.
Sub. to Phys. Rev. D

- Use frequentist interpretation (similar to Dalitz plot method) to obtain weak phase γ and hadronic parameters r_B, δ_B from $R_{CP\pm}$ and $A_{CP\pm}$ observables

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

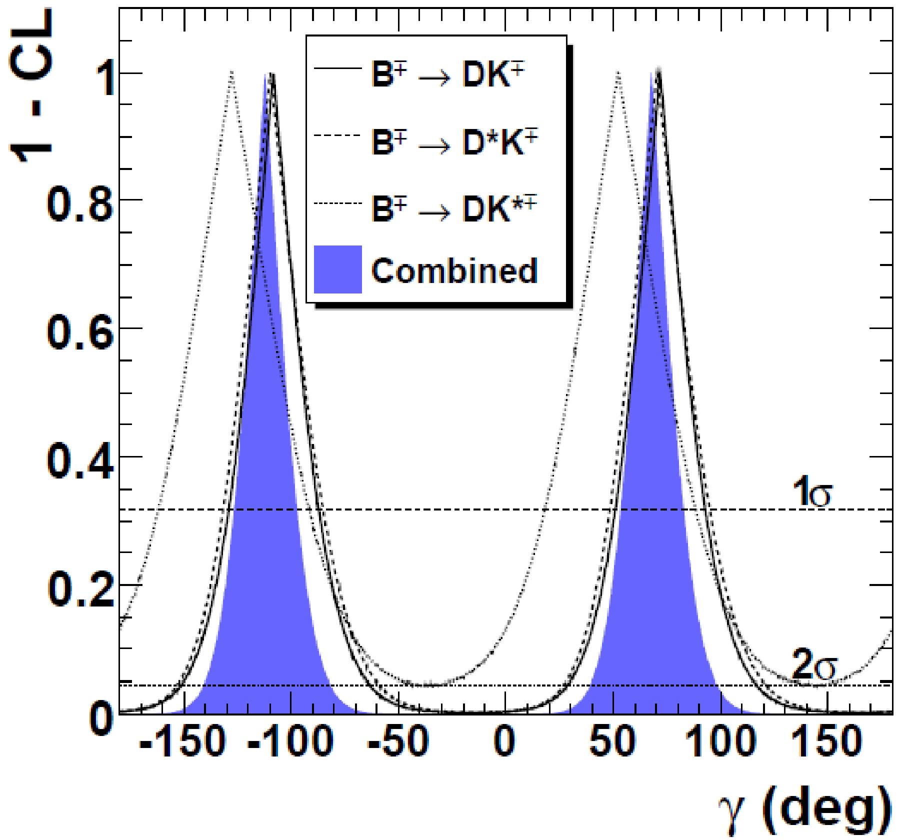
Weak sensitivity to r_B

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



BaBar Dalitz plot method

Summary and outlook



$$\gamma\ (\text{mod}\ 180°) = (\,68 \pm 14 \pm 4 \pm 3\,)°$$

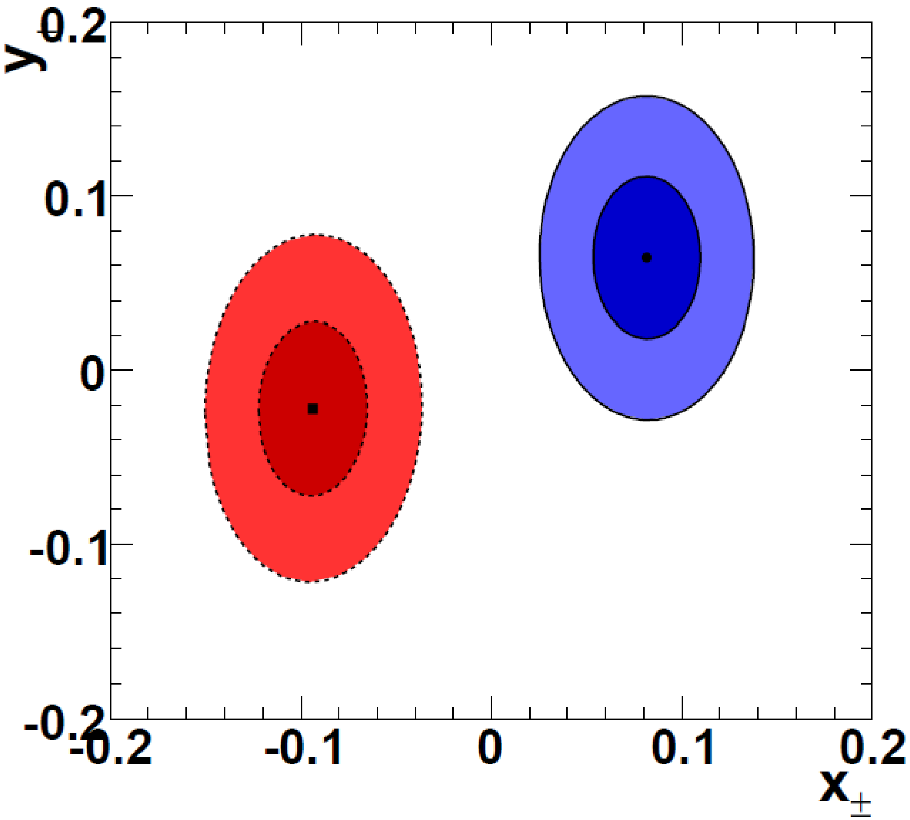
stat syst model

3.5σ significance of CPV, $B^{\pm} \to D(*)K(*)^{\pm}$ combined, Dalitz only

3.6σ significance of CPV, $B^{\pm} \to DK^{\pm}$ only, GLW only

- Recent progress on γ, the hardest UT angle to measure
- BaBar Dalitz plot method approach drives the measurement and benefited from synergy with D-mixing analysis (e.g. reduction of experimental uncertainties inherent to the model uncertainty) (see Matt Bellis talk later in this session)
- First sign of an ADS signal in $B^{\pm} \to DK^{\pm}$ and $B^{\pm} \to D^{*} K^{\pm}$
- Compelling evidence of direct CPV in $B^{\pm} \to D(*)K^{(*)\pm}$ decays

Summary and outlook



$$x_- - x_+(\mathrm{Dalitz+GLW}) = 0.175 \pm 0.040$$

4.4σ significance of CPV in $B^\pm \to DK^\pm$ only, Dalitz+GLW combined

- Recent progress on γ, the hardest UT angle to measure
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Summary and outlook

Experiments providing most of analyses today

3.1 GeV e^+ 9 GeV e^- 468M $B\bar{B}$ pairs	3.5 GeV e^+ 8 GeV e^- 657M $B\bar{B}$ pairs

~10-15°

Experiments that can also give results in near future

~2-3°

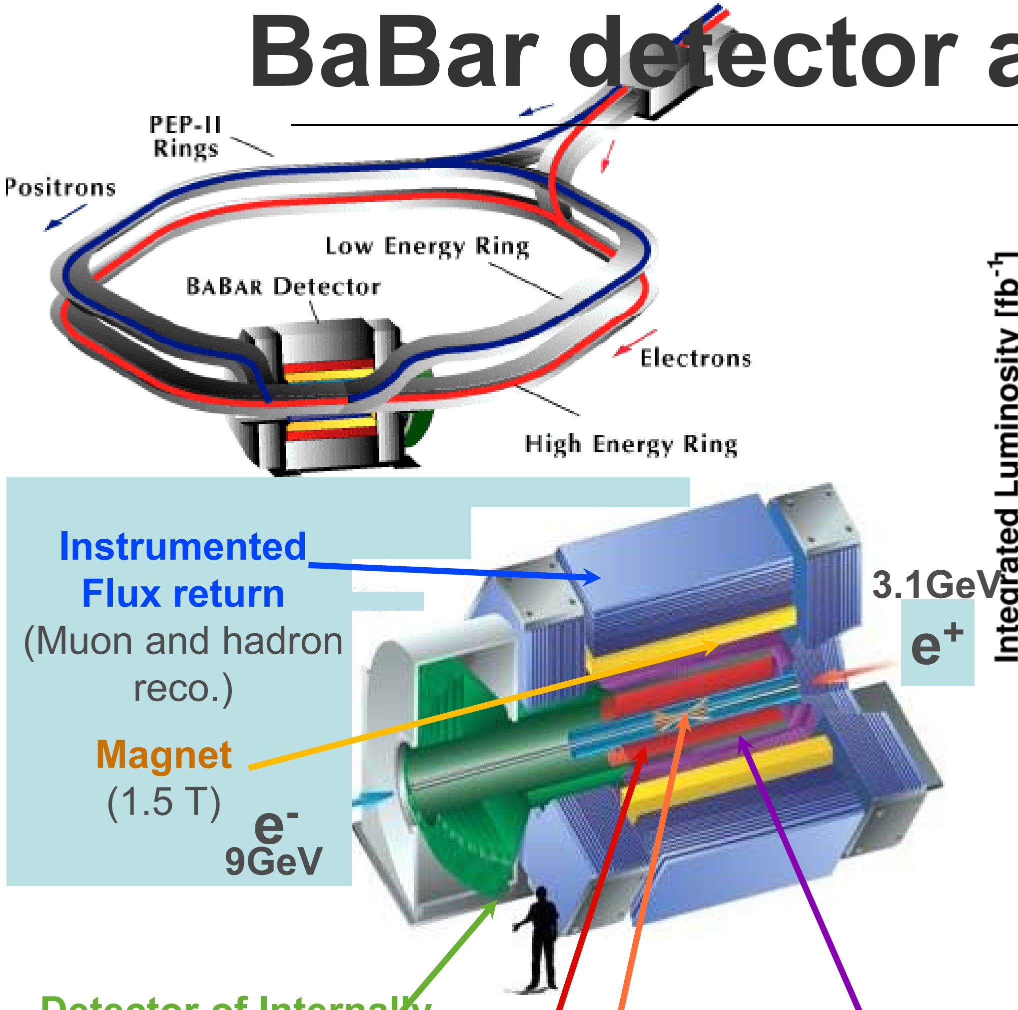
Planned facilities

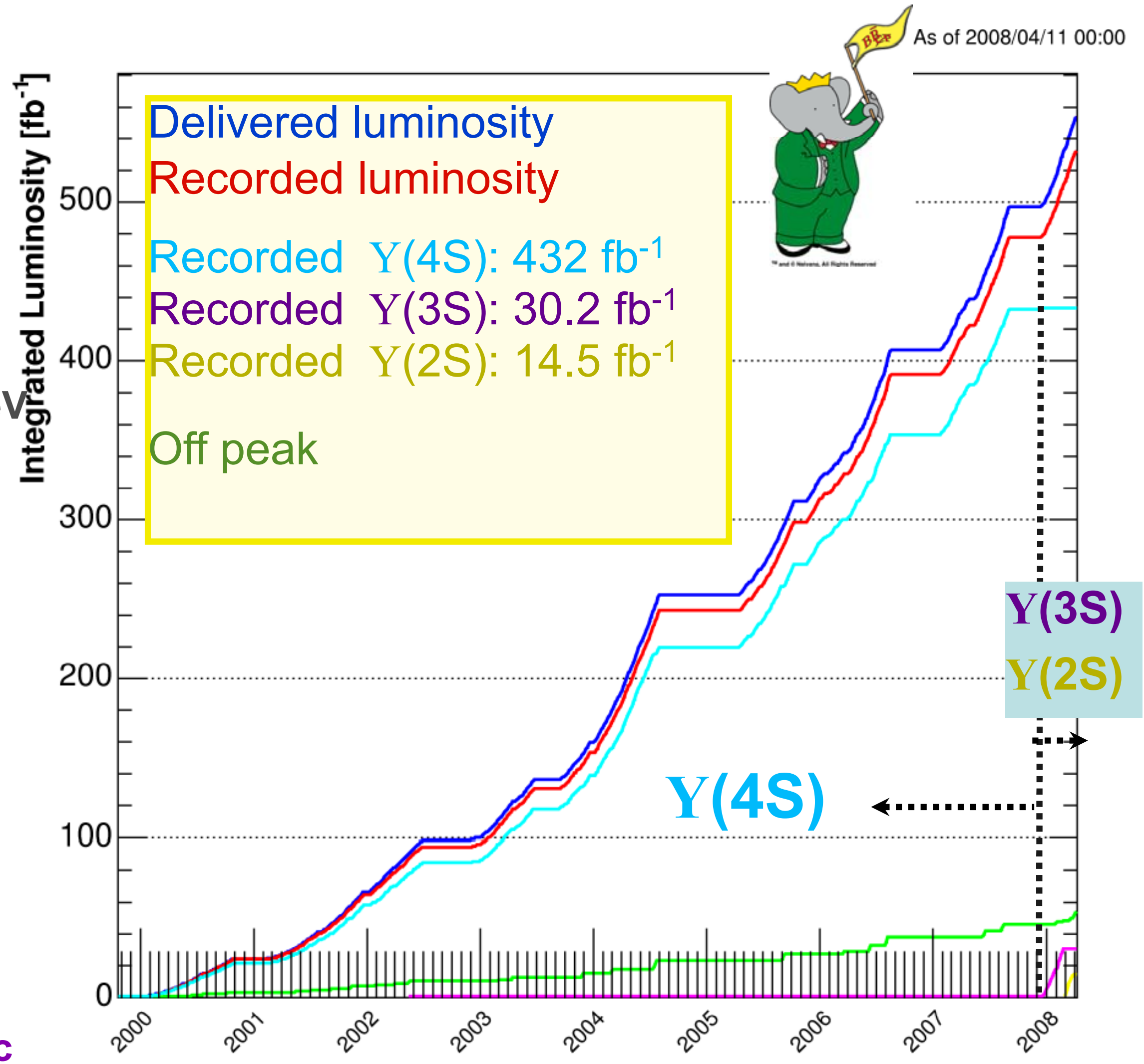
<1°

- Recent progress on γ, the hardest UT angle to measure
- BaBar Dalitz plot method approach drives the measurement and benefited from synergy with D-mixing analysis (e.g. reduction of experimental uncertainties inherent to the model uncertainty) (see Matt Bellis talk later in this session)
- First sign of an ADS signal in $B^\pm \to DK^\pm$ and $B^\pm \to D^* K^\pm$
- Compelling evidence of direct CPV in $B^\pm \to D(*)K^{(*)\pm}$ decays
- Close to "last word" from BaBar (~10-15° error)
  - Still statistics limited, even with full data sets
  - BaBar "legacy" γ average from GLW, ADS and Dalitz plot methods in progress
- Need to reduce the error in order to see possible deviations

Backup

BaBar detector and data sample





- BaBar data taking ended on 7th April 2008
- BaBar recorded ***470M*** $B\bar{B}$ at $\Upsilon(4S)$

γ from D Dalitz plot method

NEW!

- Signal yields as used in the final fit for CP parameters

arXiv:1005.1096. Sub. to Phys. Rev. Lett.

PRD81, 112002 (2010)

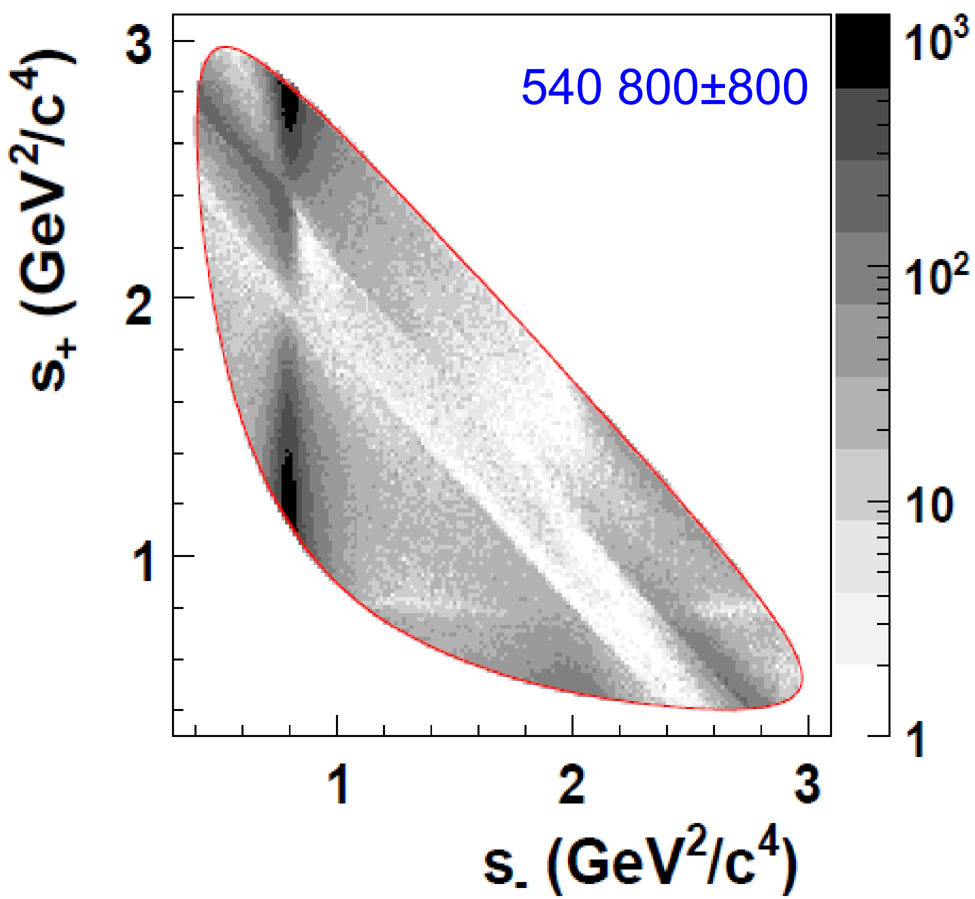
B decay mode	BaBar ($K_S\pi^+\pi^-$) 468 M $B\overline{B}$	BaBar ($K_SK^+K^-$) 468 M $B\overline{B}$	Belle ($K_S\pi^+\pi^-$) 657 M $B\overline{B}$
$B^\pm \rightarrow DK^\pm$	896±35	154±14	757±30
$B^\pm \rightarrow D^*(D\pi^0)K^\pm$	255±21	56±11	168±15
$B^\pm \rightarrow D^*(D\gamma)K^\pm$	193±19	30±7	83±10
$B^\pm \rightarrow DK^{*\pm}$	163±18	28±6	(not updated to 657 M $B\overline{B}$)

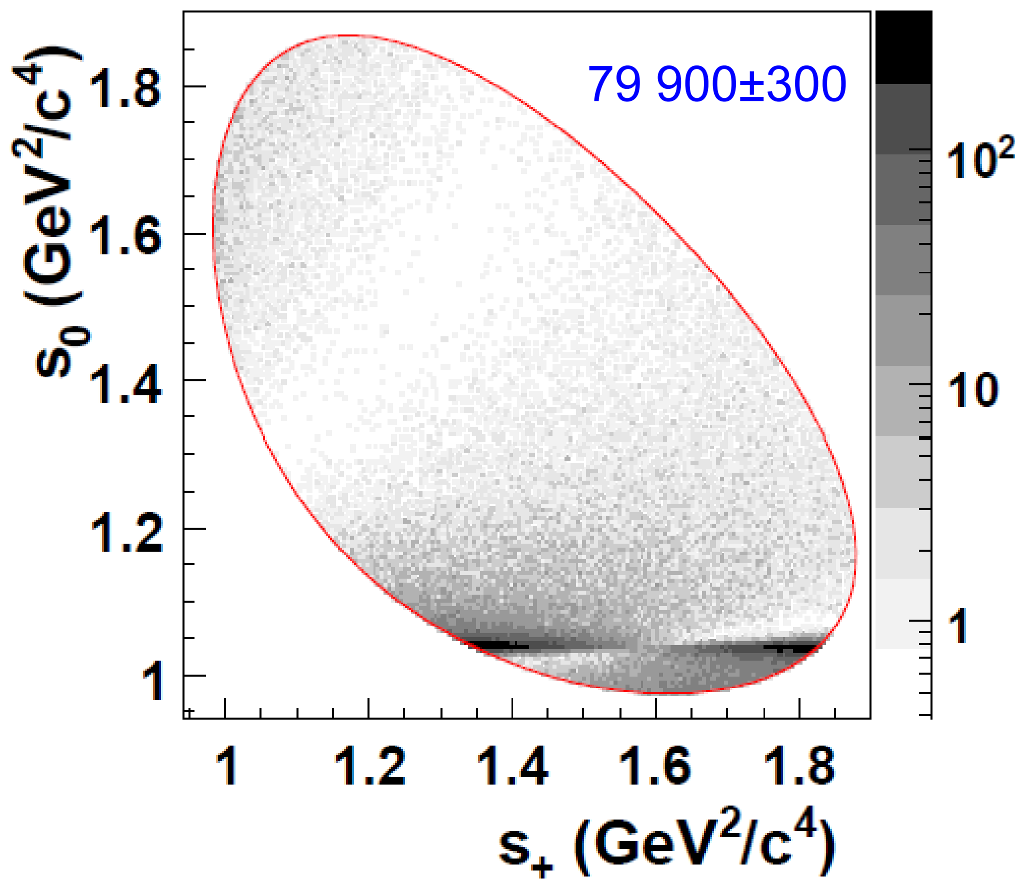
- Efficiencies improved substantially (20% to 40% relative) with respect to previous BaBar measurement (383 M $B\overline{B}$) PRD78, 034023 (2008)
  - Reprocessed data set with improved track reconstruction
  - Improved particle identification
  - Revised K_S selection criteria: negligible background from $D\rightarrow\pi^+\pi^-h^+h^-$ and $B\rightarrow Da_1(1260)$

$D \rightarrow K_S \pi^+ \pi^-, K_S K^+ K^-$ amplitude analysis

arXiv:1004.5053. Accepted by Phys. Rev. Lett.

- Extract D^0 amplitude from an independent analysis of flavor tagged D^0 mesons ($D^{*+} \rightarrow D^0 \pi^+$)
- Experimental analysis using complete data sample benefits from synergy with D-mixing analysis
  - Model determined without (reference) and with D-mixing
- Fit for amplitudes relative to CP eigenstates [$K_S \rho(770)$ and $K_S a_0(980)$] and assume no direct CPV

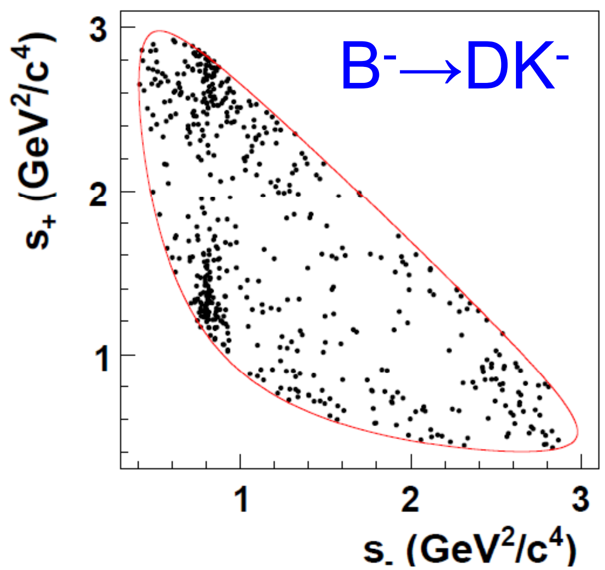


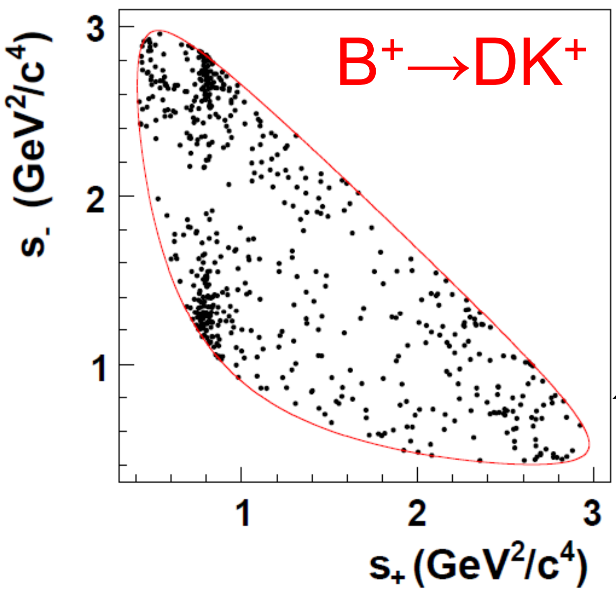


γ from D Dalitz plot method

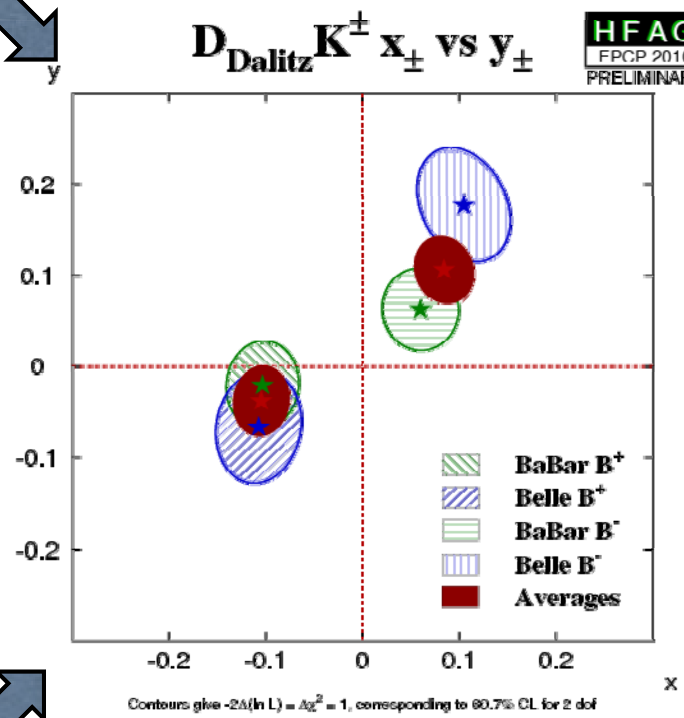
- CP violation parameters are extracted from simultaneous unbinned maximum likelihood fit to $B^{\pm} \rightarrow D^{(*)} K^{(*)\pm}$ data using m_{ES}, ΔE, *Fisher* and the Dalitz plot distributions (s+,s-)

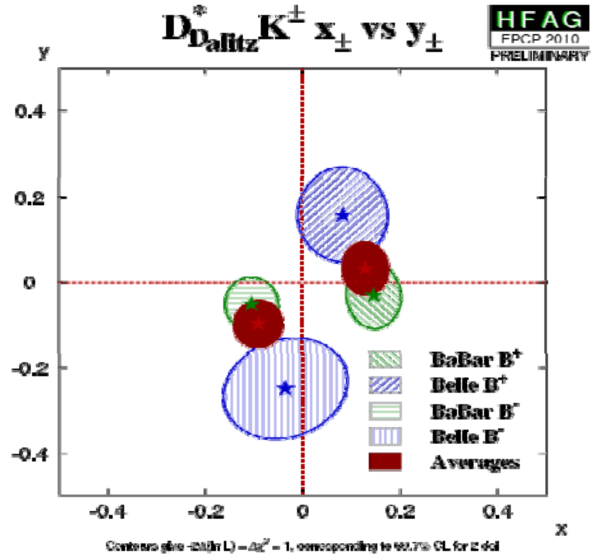
arXiv:1005.1096.
Sub. to Phys. Rev. Lett.

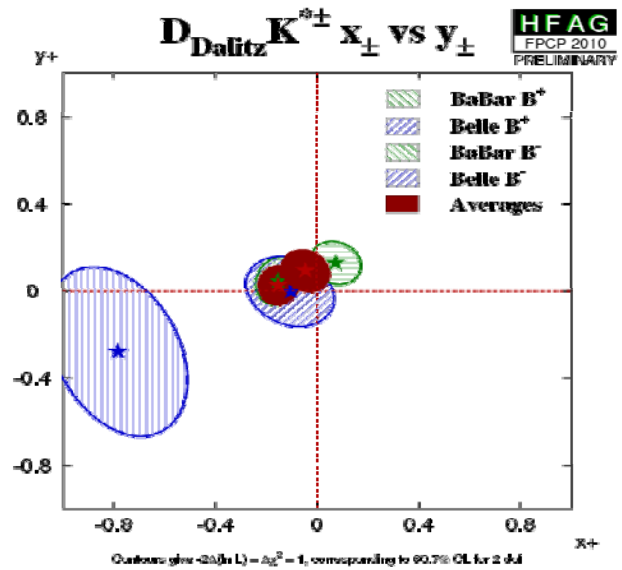




$$x_{\pm} = r_B \cos(\delta_B \pm \gamma)$$
$$y_{\pm} = r_B \sin(\delta_B \pm \gamma)$$







Most precise measurement of (x,y)

Consistent results with latest Belle results
PRD81, 112002 (2010)

http://www.slac.stanford.edu/xorg/hfag/triangle/moriond2010

γ from D Dalitz plot method

arXiv:1005.1096.
Sub. to Phys. Rev. Lett.

Source	x_-	y_-	x_+	y_+	x^*_-	y^*_-	x^*_+	y^*_+	x_{s-}	y_{s-}	x_{s+}	y_{s+}
m_{ES}, ΔE, $\mathcal{F}$ shapes	0.001	0.001	0.001	0.001	0.004	0.006	0.008	0.004	0.006	0.003	0.004	0.002
Real D^0 fractions	0.002	0.001	0.001	0.001	0.003	0.003	0.002	0.002	0.004	0.001	0.001	0.001
Charge-flavor correlation	0.003	0.003	0.002	0.001	0.005	0.005	0.008	0.002	0.001	0.001	0.003	0.001
Efficiency in the DP	0.003	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.001
Background DP distributions	0.005	0.002	0.005	0.003	0.003	0.002	0.004	0.004	0.010	0.004	0.007	0.002
$B^- \to D^{*0}K^-$ cross-feed	–	–	–	–	0.002	0.003	0.009	0.002	–	–	–	–
CP violation in $D\pi$ and $B\overline{B}$	0.002	0.001	0.001	0.001	0.017	0.001	0.008	0.004	0.017	0.002	0.011	0.001
Non-K^* $B^- \to DK^0_S\pi^-$ decays	–	–	–	–	–	–	–	–	0.020	0.026	0.025	0.036
Total experimental	0.007	0.004	0.006	0.004	0.019	0.009	0.017	0.008	0.029	0.027	0.029	0.036

Source	x_-	y_-	x_+	y_+	x^*_-	y^*_-	x^*_+	y^*_+	x_{s-}	y_{s-}	x_{s+}	y_{s+}
Mass and width of Breit-Wigner's	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002
$\pi\pi$ S-wave parameterization	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002
$K\pi$ S-wave parameterization	0.001	0.004	0.003	0.008	0.001	0.006	0.002	0.004	0.003	0.002	0.003	0.007
Angular dependence	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.001
Blatt-Weisskopf radius	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
Add/remove resonances	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002
DP efficiency	0.003	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.004	0.002	0.003	0.001
Background DP shape	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Mistag rate	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.003	0.001	0.001
Effect of mixing	0.003	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.003	0.001
DP complex amplitudes	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.002
Total D^0 decay amplitude model	0.006	0.006	0.007	0.009	0.002	0.007	0.003	0.006	0.007	0.006	0.006	0.008

γ from D Dalitz plot method

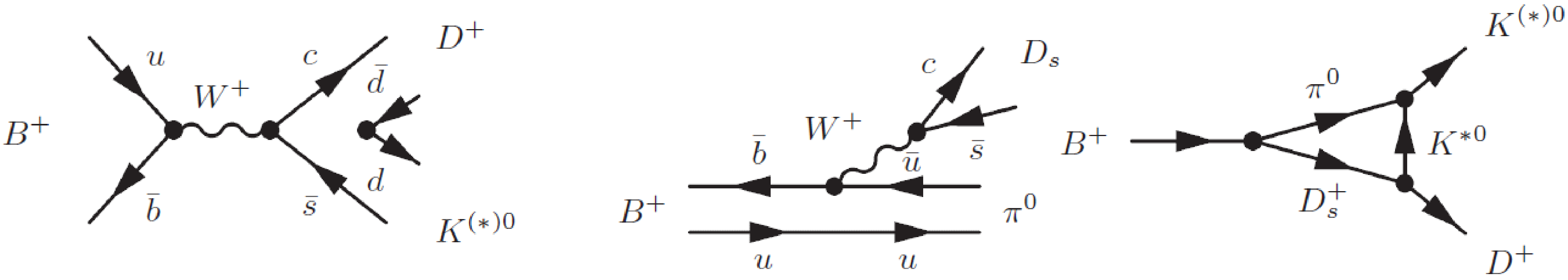
arXiv:1005.1096.
Sub. to Phys. Rev. Lett.

	Real part (%)	Imaginary part (%)
z_-	$6.0 \pm 3.9 \pm 0.7 \pm 0.6$	$6.2 \pm 4.5 \pm 0.4 \pm 0.6$
z_+	$-10.3 \pm 3.7 \pm 0.6 \pm 0.7$	$-2.1 \pm 4.8 \pm 0.4 \pm 0.9$
z_-^*	$-10.4 \pm 5.1 \pm 1.9 \pm 0.2$	$-5.2 \pm 6.3 \pm 0.9 \pm 0.7$
z_+^*	$14.7 \pm 5.3 \pm 1.7 \pm 0.3$	$-3.2 \pm 7.7 \pm 0.8 \pm 0.6$
z_{s-}	$7.5 \pm 9.6 \pm 2.9 \pm 0.7$	$12.7 \pm 9.5 \pm 2.7 \pm 0.6$
z_{s+}	$-15.1 \pm 8.3 \pm 2.9 \pm 0.6$	$4.5 \pm 10.6 \pm 3.6 \pm 0.8$

Parameter	68.3% CL	95.4% CL
γ (°)	68^{+15}_{-14} {4, 3}	[39, 98]
r_B (%)	9.6 ± 2.9 {0.5, 0.4}	[3.7, 15.5]
r_B^* (%)	$13.3^{+4.2}_{-3.9}$ {1.3, 0.3}	[4.9, 21.5]
κr_s (%)	$14.9^{+6.6}_{-6.2}$ {2.6, 0.6}	< 28.0
δ_B (°)	119^{+19}_{-20} {3, 3}	[75, 157]
δ_B^* (°)	-82 ± 21 {5, 3}	[−124, −38]
δ_s (°)	111 ± 32 {11, 3}	[42, 178]

Other hadronic parameters relevant for γ

- Updated search for $B^+ \to D^+ K^0$ and $B+ \to D^+ K^{*0}$
  - Can only proceed through annihilation or rescattering



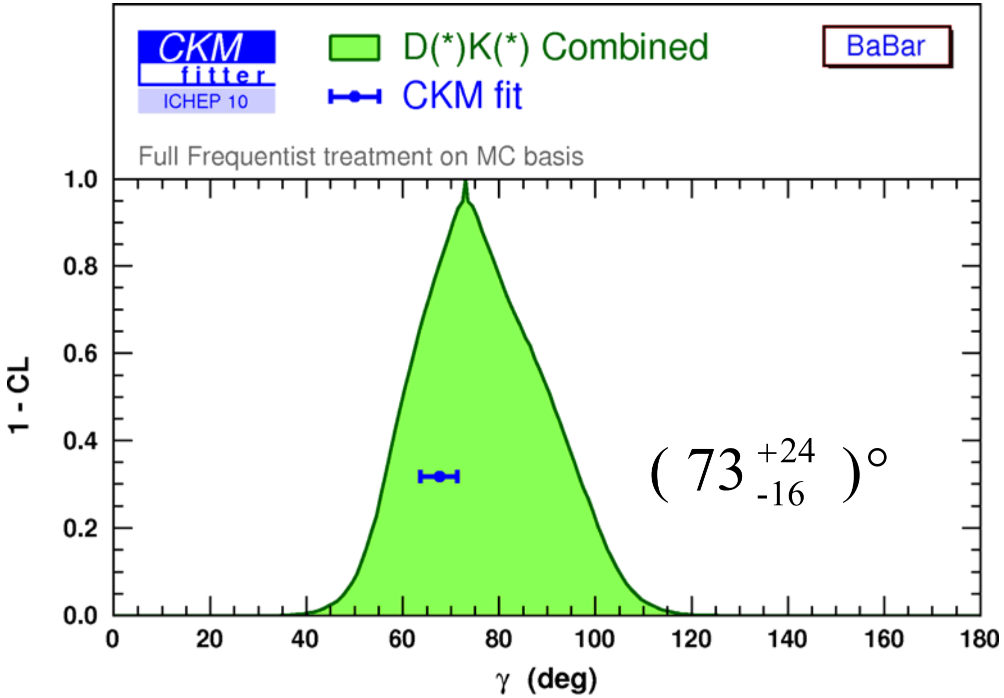
- Allows an estimation of r_B^0 for B^0 from r_B for B^+ needed for
  - $B^0 \to D^0 K^0$ measures $r_B^0 \sin(2\beta+\gamma)$ in time-dependent asymmetry
  - $B^0 \to D^0 K^{*0}$ measures γ in direct CPV (similar to B^+)
- BaBar analysis with full data sample: 468 M $B\overline{B}$
  - No evidence for signals

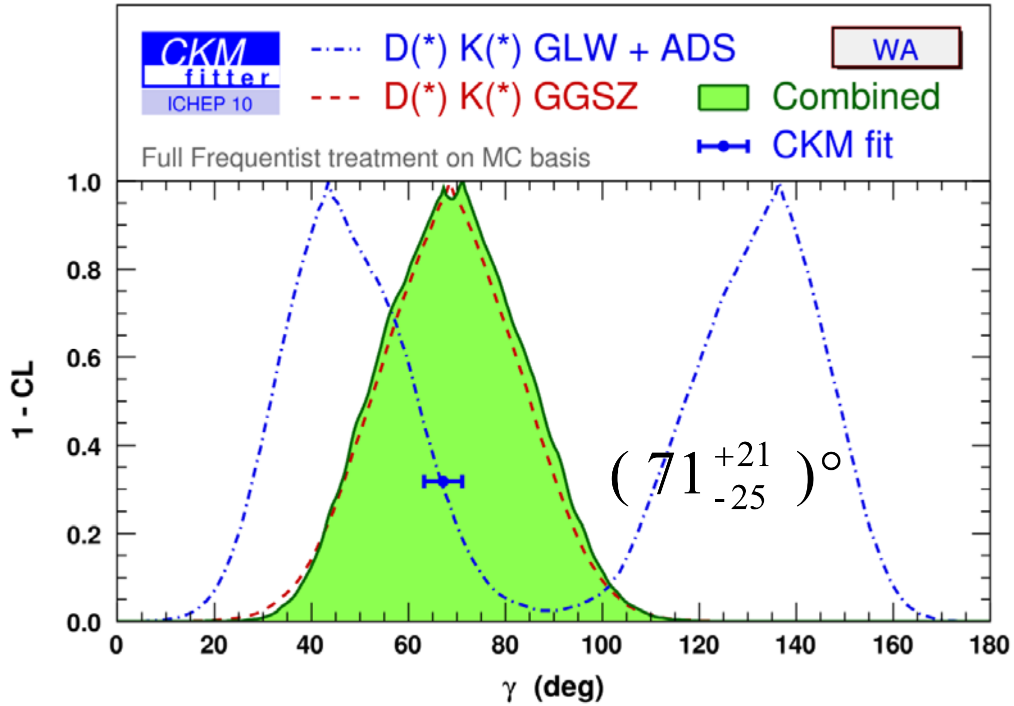
arXiv:1005.0068. Submitted to PRD

$$\mathcal{B}(B^+ \to D^+ K^0) < 2.9 \times 10^{-6},\ 90\%\text{C.L.}$$

$$\mathcal{B}(B^+ \to D^+ K^{*0}) < 3.0 \times 10^{-6},\ 90\%\text{C.L.}$$

BaBar vs WA





Courtesy of V. Tisserand and the CKM fitter group

μ supremum method used to combine HFAG averages of experimental inputs (conservative, but guarantees coverage).
See Karim Trabelsi's talk at CKM 2008 for details.