ϕ_3 measurements

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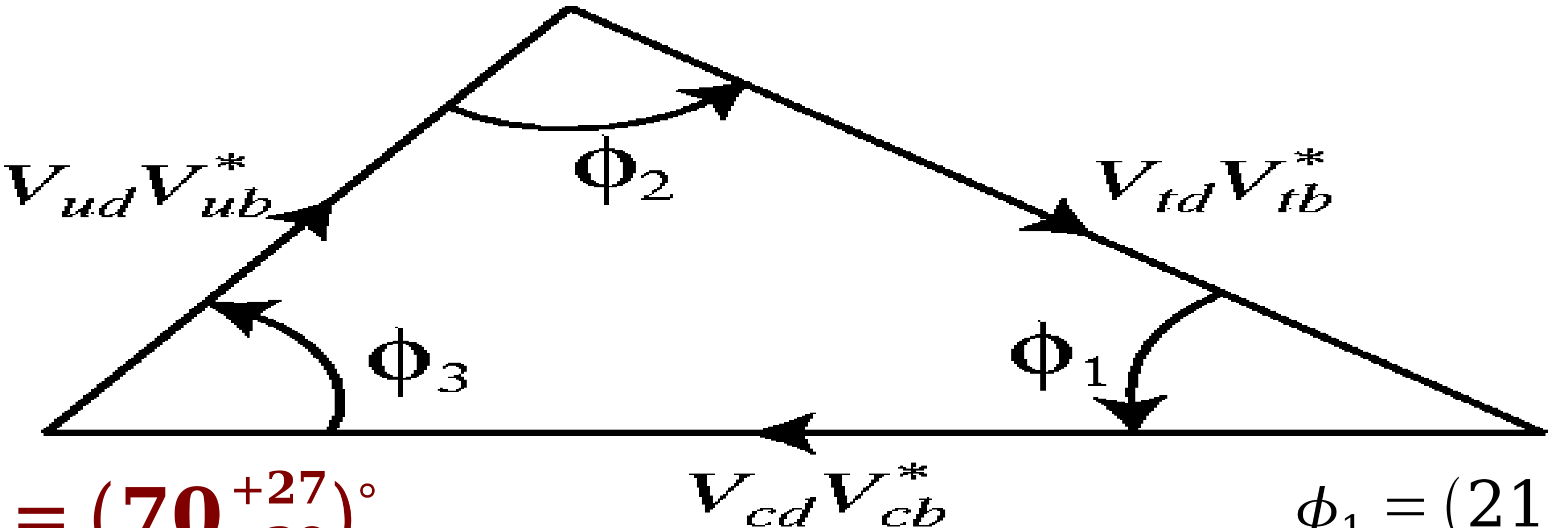
sBGM, 10 Dec, 2008

- B.Golob: use the values in the draft of the superB physics paper, i.e. 5 ab^{-1} and 50 ab^{-1}.
  ...(at least wherever possible) strictly divide the errors into stat., scaling and non-scaling systematics.
- T.Browder: ϕ_3 sensitivity of SuperBelle compared to LHCb

Les promesses n'engagent que ceux y croient...

News from the Unitarity Triangle

$\phi_2 = (88.4^{+5.6}_{-4.9})^\circ$
(WA, CKMfitter, ICHEP08)



$\boldsymbol{\phi_3 = (70^{+27}_{-29})^\circ}$
(WA, CKMfitter, CKM08)

$\phi_1 = (21.1 \pm 0.9)^\circ$
(WA, HFAG, ICHEP08)

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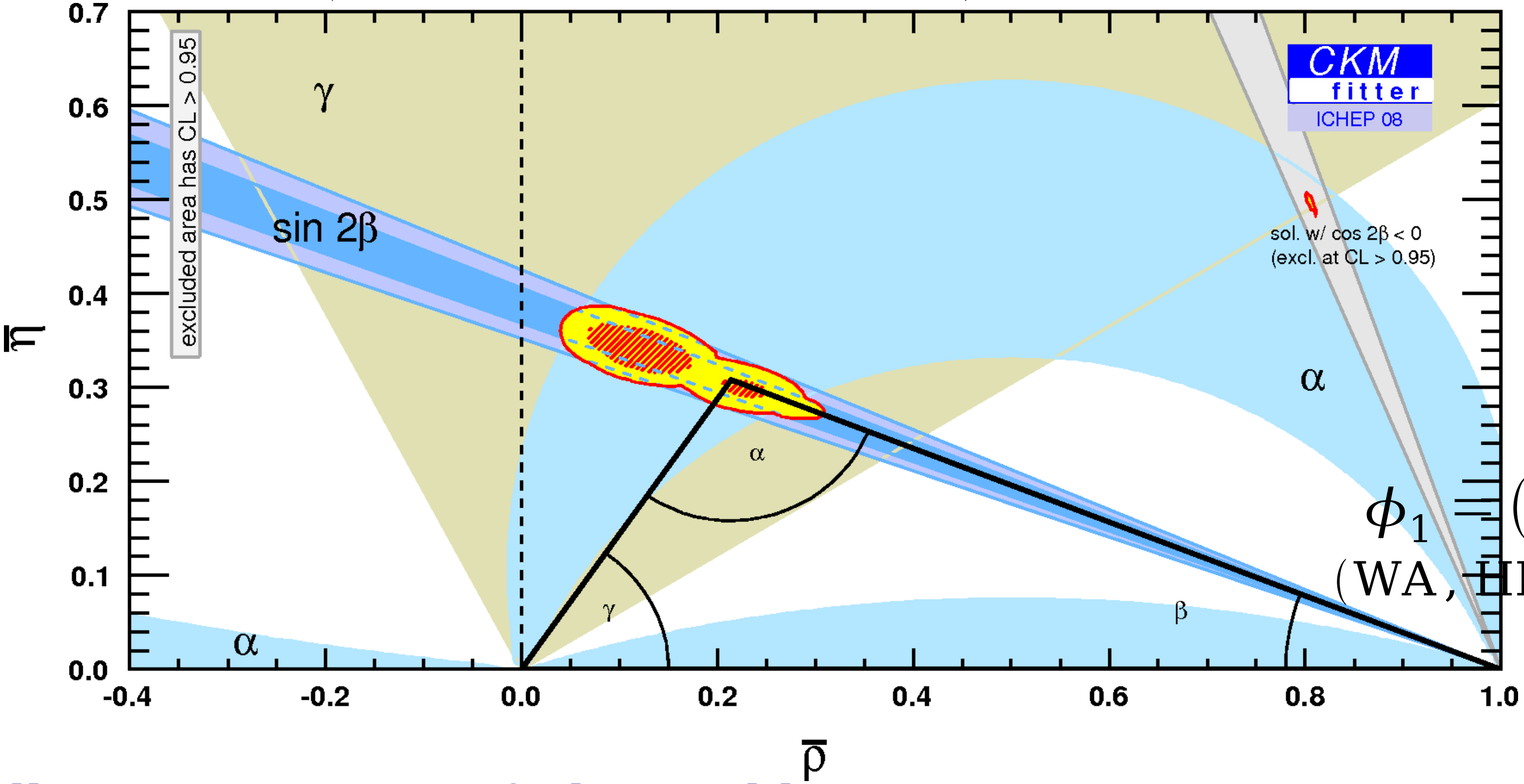


$$\phi_1 = (21.1 \pm 0.9)^\circ$$
(WA, HFAG, ICHEP08)

All measurements of observables sensitive to ϕ_3 are statistically limited

$$\boldsymbol{\phi_3 = (70^{+27}_{-29})^\circ}$$ (WA, CKMfitter, CKM08)

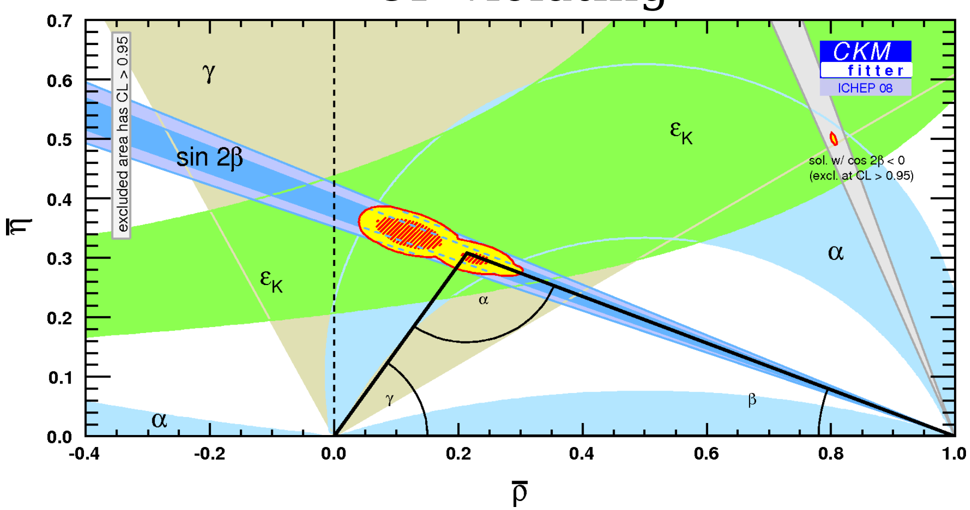
Although not all the statistics yet analyzed by Belle

Motivations

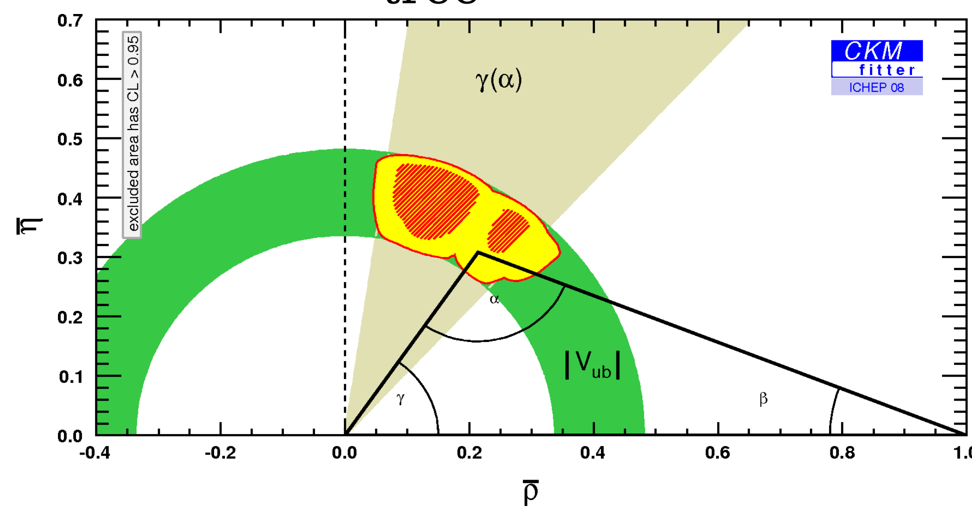
- Overconstrain the CKM matrix : measure fundamental parameters, constrain new physics effects

- Measure the 4 free paremeters in various ways :
  - CP conserving $\{|V_{us}|, |V_{cb}|, |V_{td}|, |V_{ub}|\}$
  - CP violating $\{\epsilon_K, \phi_s, \phi_1, \phi_3\}$
  - Tree level $\{\ldots, \ldots, |V_{ub}|, \phi_3\}$
  - Loop level $\{\ldots, \ldots, |V_{td}|, \phi_1\}$
  - ...

CP violating



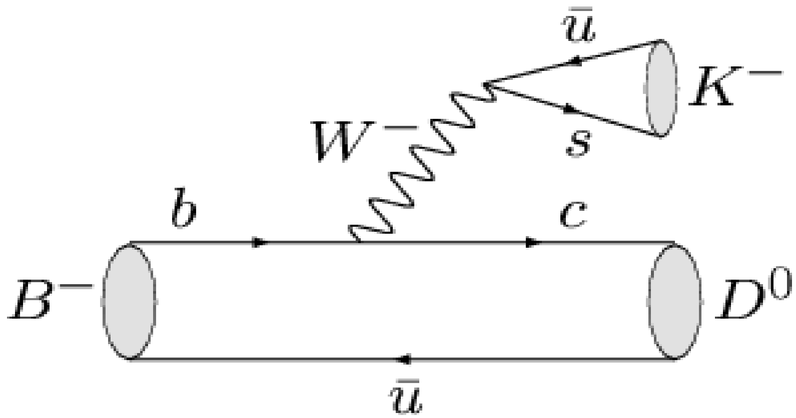
tree



- ~1 % seems to be the right level to test NP

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

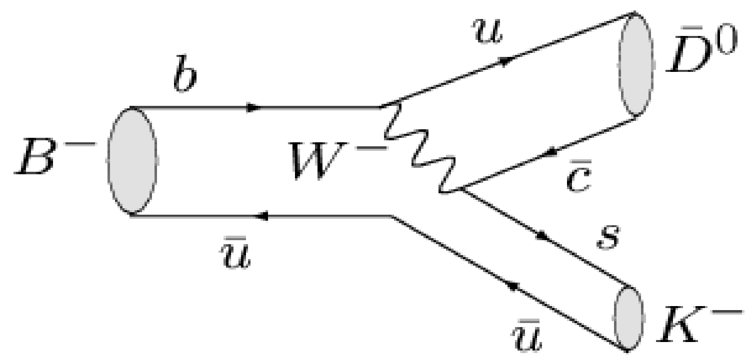
- Theoretically pristine $B \to DK$ approach
- Access γ via interference between $B^- \to D^0 K^-$ and $B^- \to \overline{D}^0 K^-$



color allowed

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

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



color suppressed

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

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

relative magnitude of suppressed amplitude is r_B

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

relative weak phase is ϕ_3, 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 $D \to K_S\pi^+\pi^-$, $K_SK^+K^-$

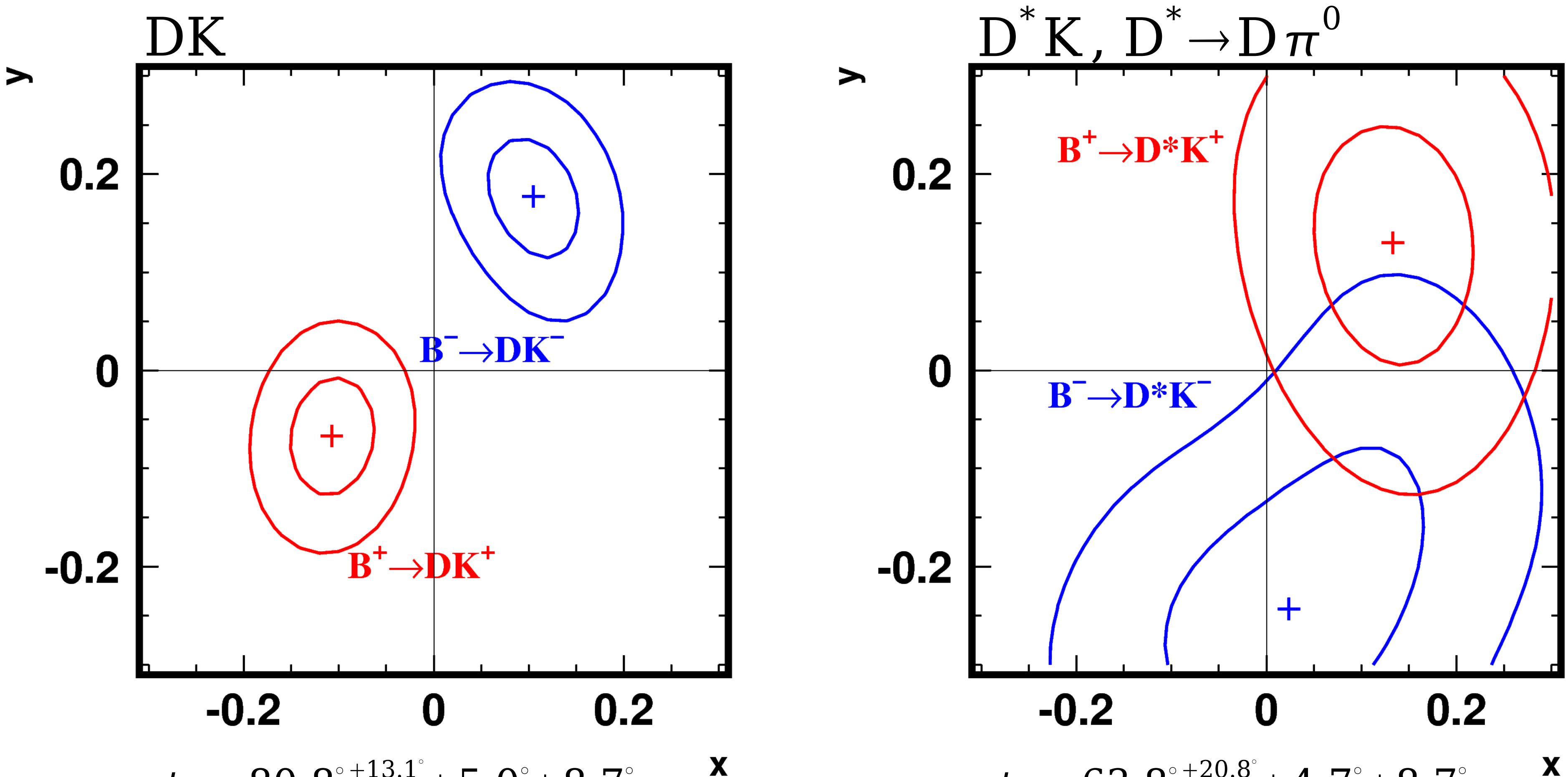
    GGSZ (Dalitz) method (Giri-Grossman-Soffer-Zupan)
- Largest effects due to
  - charm mixing
  - charm CP violation

  } negligible [PRD 72, 031501 (2005)]
- Different B decays (DK, D^*K, DK^*)
  - different hadronic factors (r_B, δ_B) for each

Dalitz $B \to D^{(*)}(K_S \pi\pi)K$ [arXiv:0803.3375]

using 605 fb^{-1}

$$x_\pm = r_B \cos(\delta_B \pm \phi_3)$$
$$y_\pm = r_B \sin(\delta_B \pm \phi_3)$$



DK:

$$\phi_3 = 80.8^{\circ}{}^{+13.1^\circ}_{-14.8^\circ} \pm 5.0^\circ \pm 8.7^\circ$$
$$r_B = 0.161^{+0.040}_{-0.038} \pm 0.011 \pm 0.049$$
$$\delta_B = 137.4^{\circ}{}^{+13.0^\circ}_{-15.7^\circ} \pm 4.0^\circ \pm 22.9^\circ$$

D^*K:

$$\phi_3 = 63.8^{\circ}{}^{+20.8^\circ}_{-22.9^\circ} \pm 4.7^\circ \pm 8.7^\circ$$
$$r_B = 0.208^{+0.085}_{-0.083} \pm 0.015 \pm 0.049$$
$$\delta_B = 342.0^{\circ}{}^{+21.4^\circ}_{-22.9^\circ} \pm 3.7^\circ \pm 22.9^\circ$$

$$\phi_3 = 76^{\circ}{}^{+12^\circ}_{-13^\circ}(\mathrm{stat}) \pm 4^\circ(\mathrm{syst}) \pm 9^\circ(\mathrm{model})$$

Dalitz $B \to D^{(*)}(K_S \pi \pi) K$ [arXiv:0803.3375]

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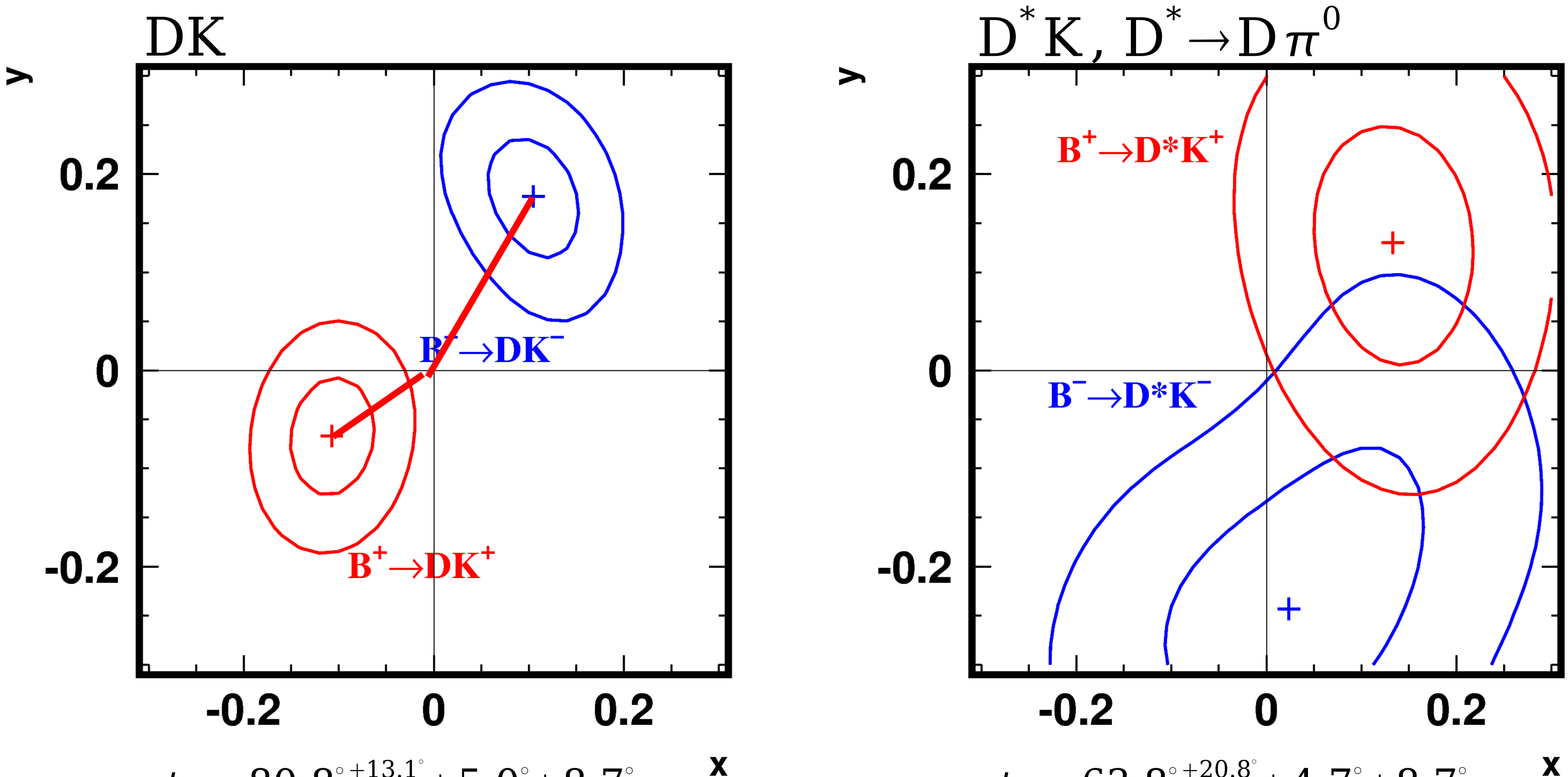

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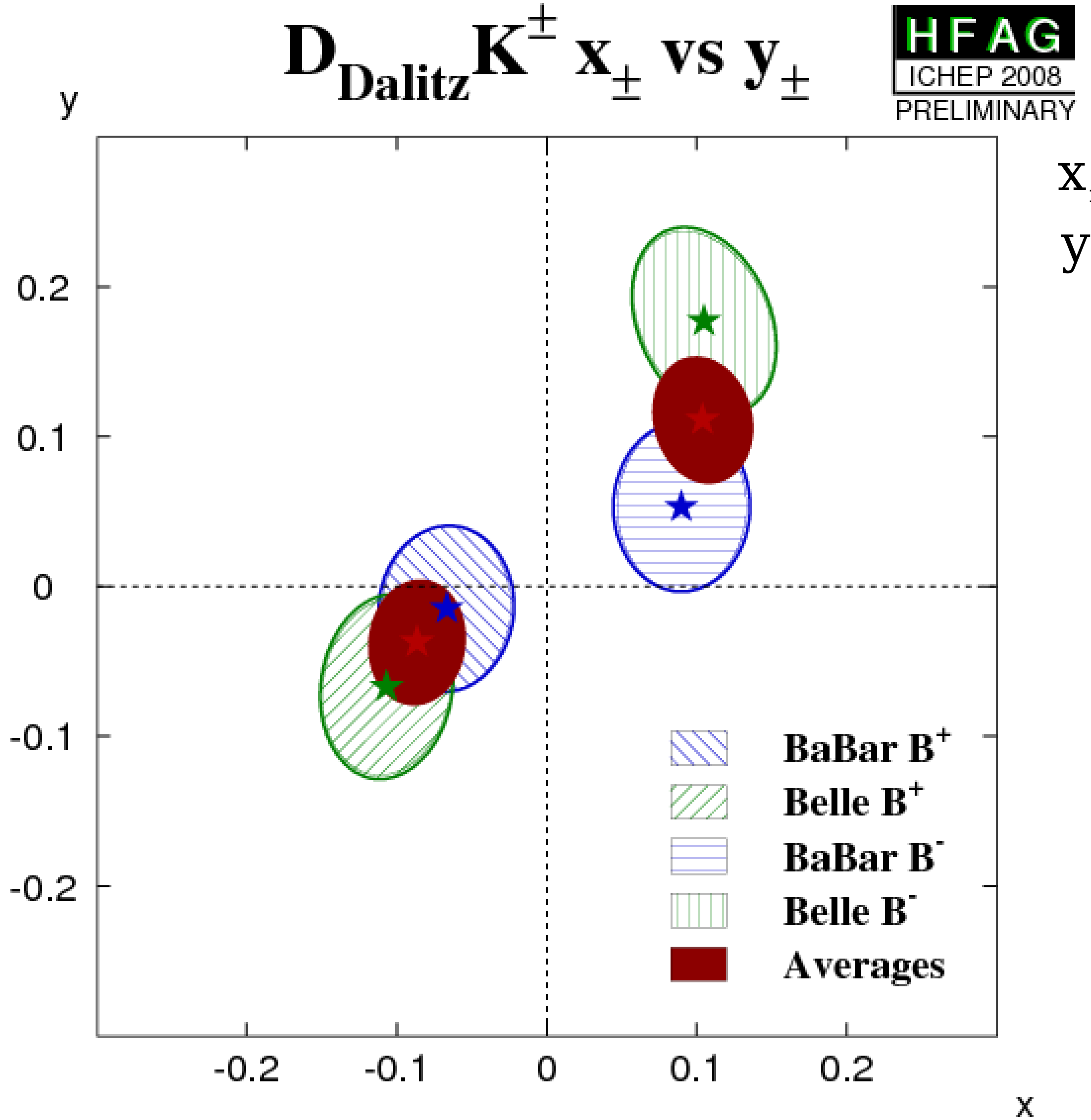
Dalitz B→DK



$$x_{\pm} = r_B \cos(\delta_B \pm \phi_3)$$
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DK, Belle

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DK, BaBar

$$\phi_3 \sim 63^{\circ} \pm 28^{\circ}$$
$$r_B = 0.086 \pm 0.035$$
$$\delta_B = 109^{\circ}{}^{+28}_{-31^{\circ}}$$

γ and r_B... (BaBar example)

analysis with $227\times10^6 B\bar{B}$ **[PRL95, 121802 (2005)]**

$r_B(DK) = 0.12 \pm 0.08 \pm 0.03 \pm 0.04$

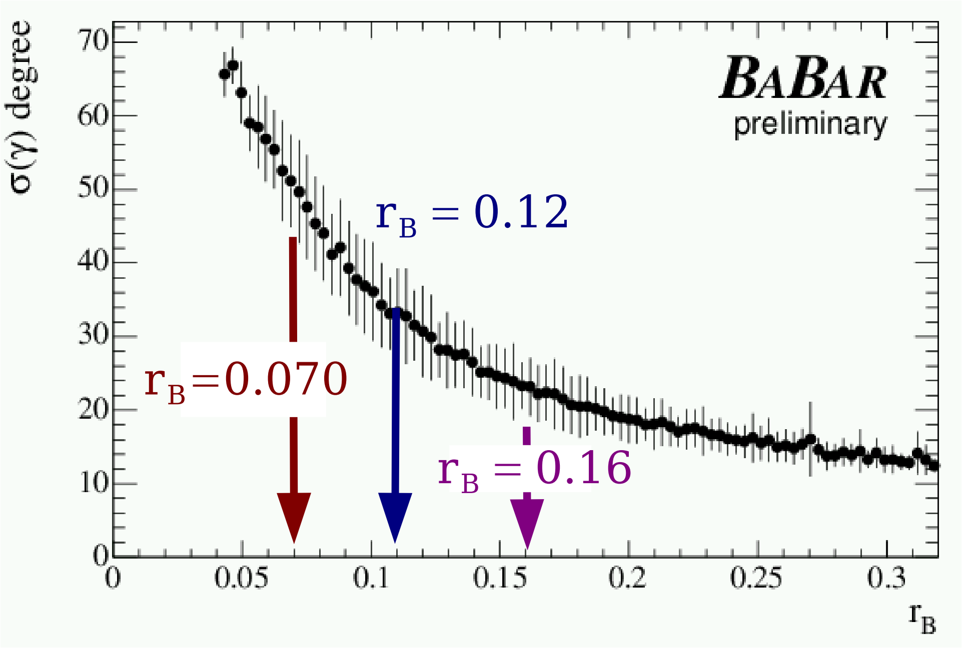
$$\boldsymbol{\gamma = 70^\circ \pm 31^\circ(\text{stat})^{+12^\circ}_{-10^\circ}(\text{syst})^{+14^\circ}_{-11^\circ}(\text{model})}$$

analysis with $347\times10^6 B\bar{B}$ **[hep−ex/0607104]** $r_B(DK) < 0.140$

$$\boldsymbol{\gamma = 92^\circ \pm 41^\circ(\text{stat}) \pm 11^\circ(\text{syst}) \pm 12^\circ(\text{model})}$$

uncertainty on γ scales as $1/r_B$! ($r_B = 0 \Rightarrow$ no constraint on γ)

DK case



- the r_B assumption for the extrapolation is very relevant
- as the stat increases, the sophisticated statistical treatment not necessary anymore

Dalitz $B \to D^{(*)}(K_S\pi\pi)K$ [arXiv:0803.3375]

using 605 fb^{-1}

$x_\pm = r_B \cos(\delta_B \pm \phi_3)$
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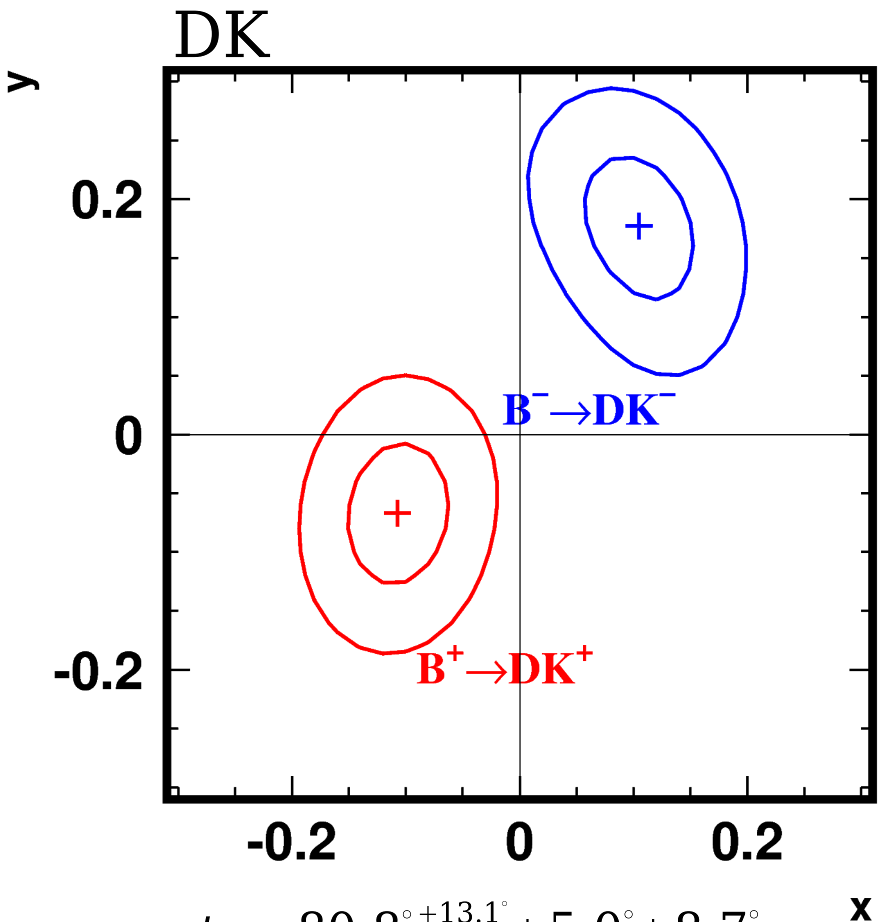

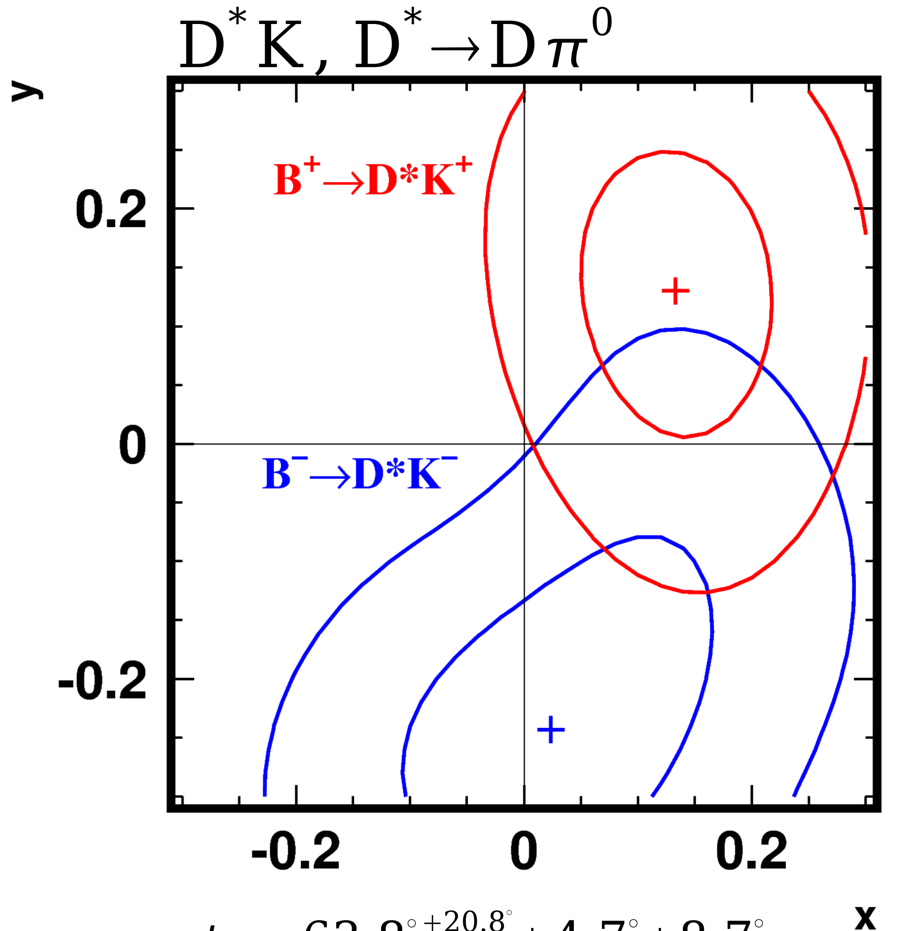

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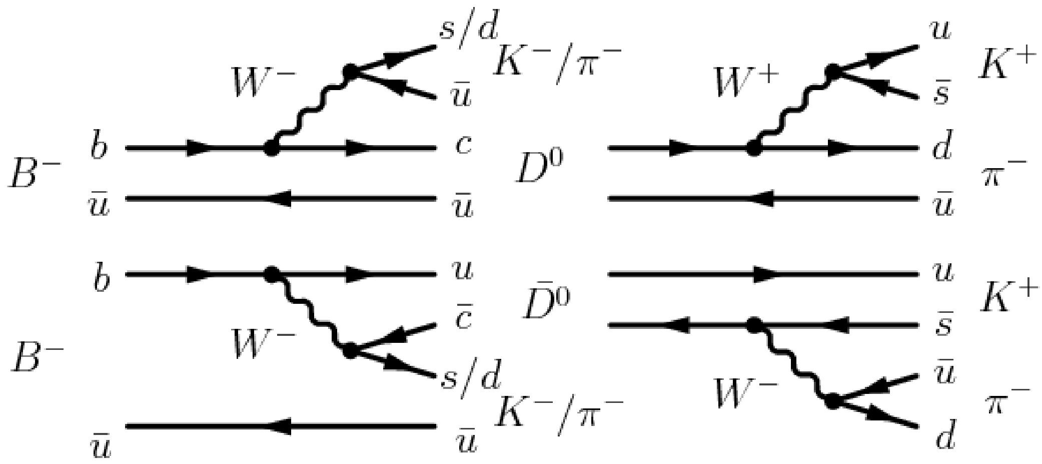
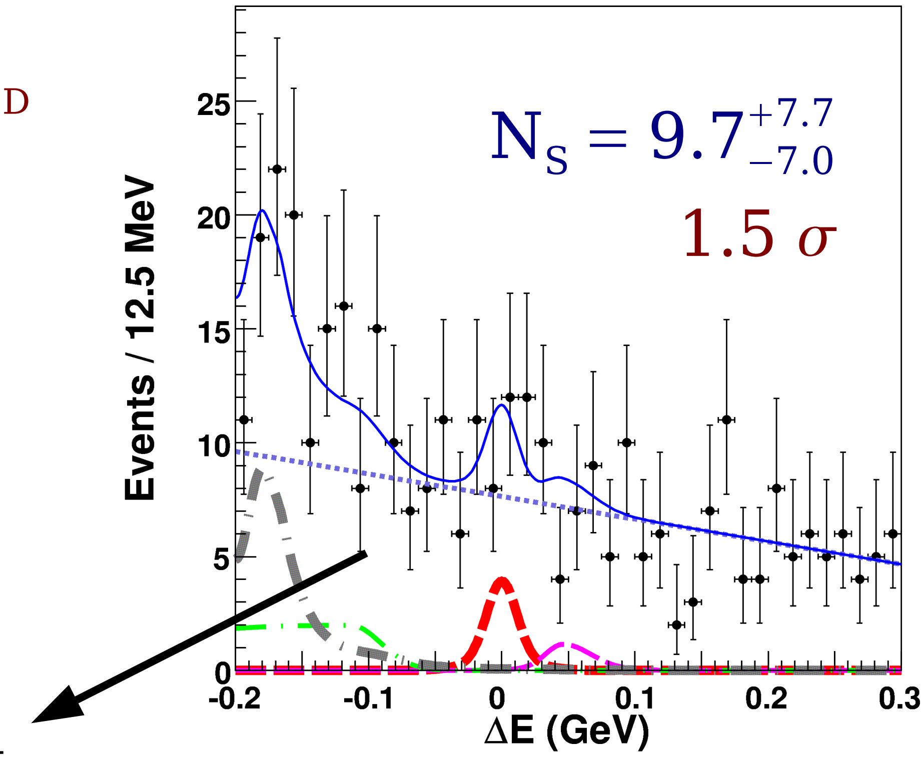
ADS method: $D \to K\pi$

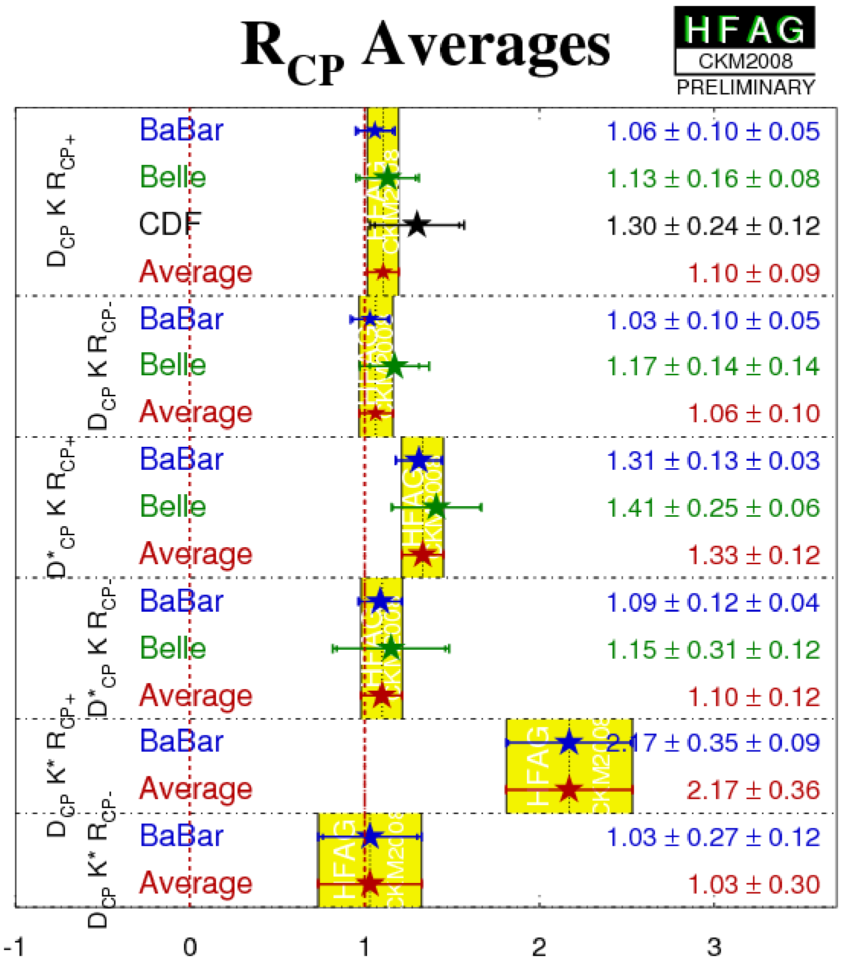


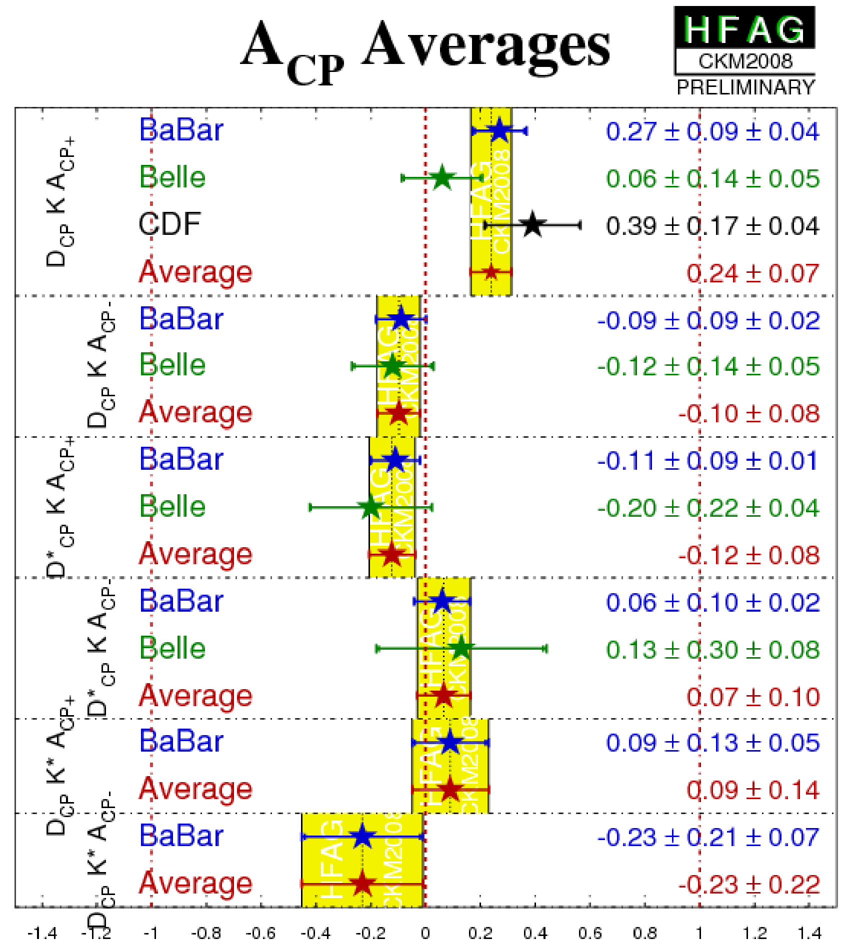
- interfering amplitudes are comparable
- introduce 2 new parameters: r_D, δ_D
- but measured by CLEO ($\to$ BESIII)
- continuum background dominates

[PRD 78, 071901 (2008)]



GLW method   observables $R_{CP^\pm}$, $A_{CP^\pm}$

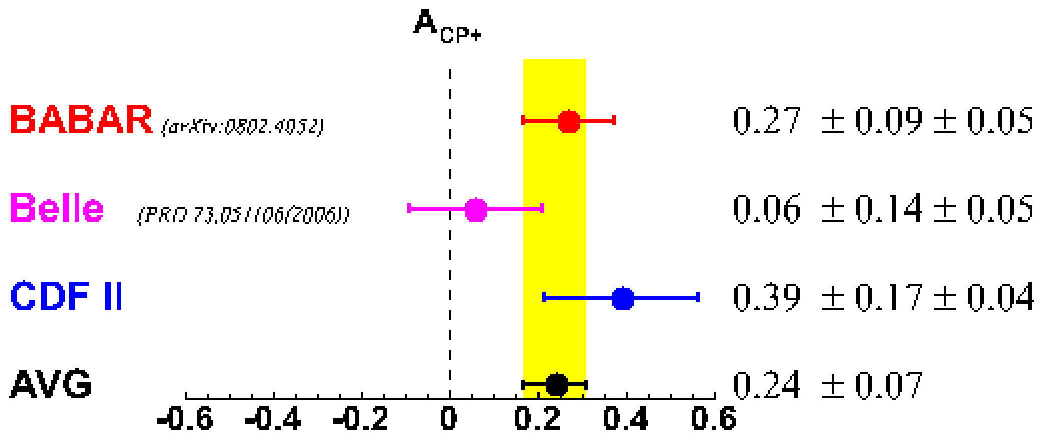




- no charge asymmetry yet observed
- BaBar ($\sim 350\,\mathrm{fb}^{-1}$), Belle ($\sim 250\,\mathrm{fb}^{-1}$)

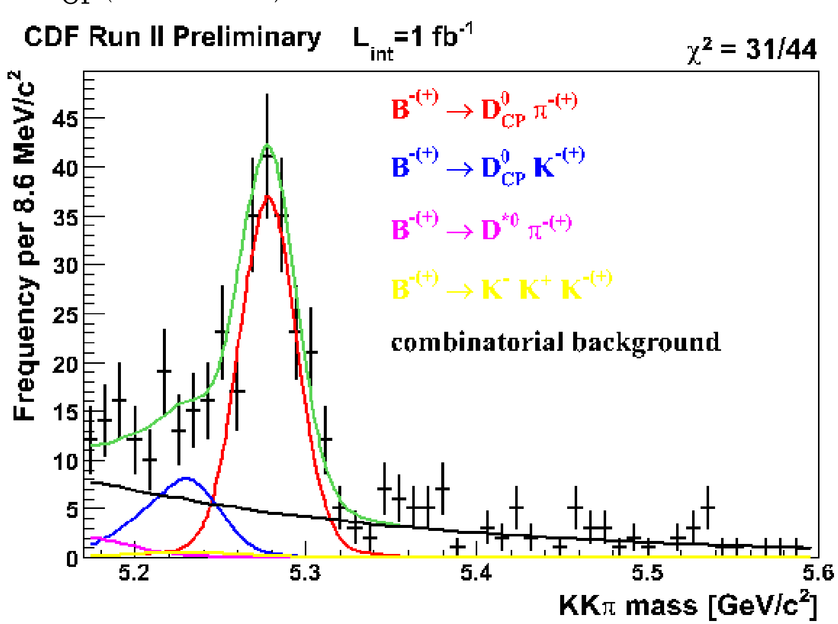
Other than B-factories: CDF result, ICHEP08

even with a very modest PID system...

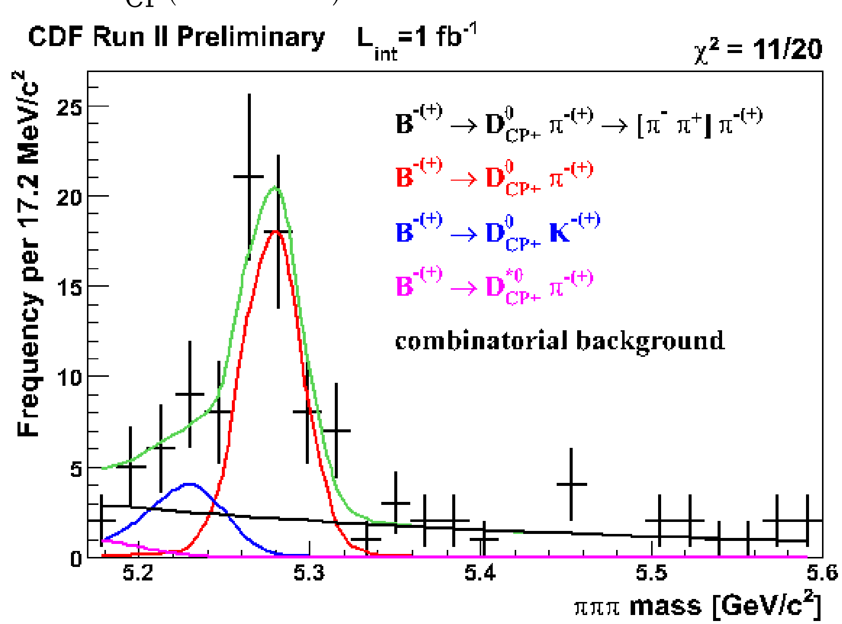


mass projection on a kaon enriched sample (k>0.5)

$D_{CP}(\rightarrow K^+K^-)K$

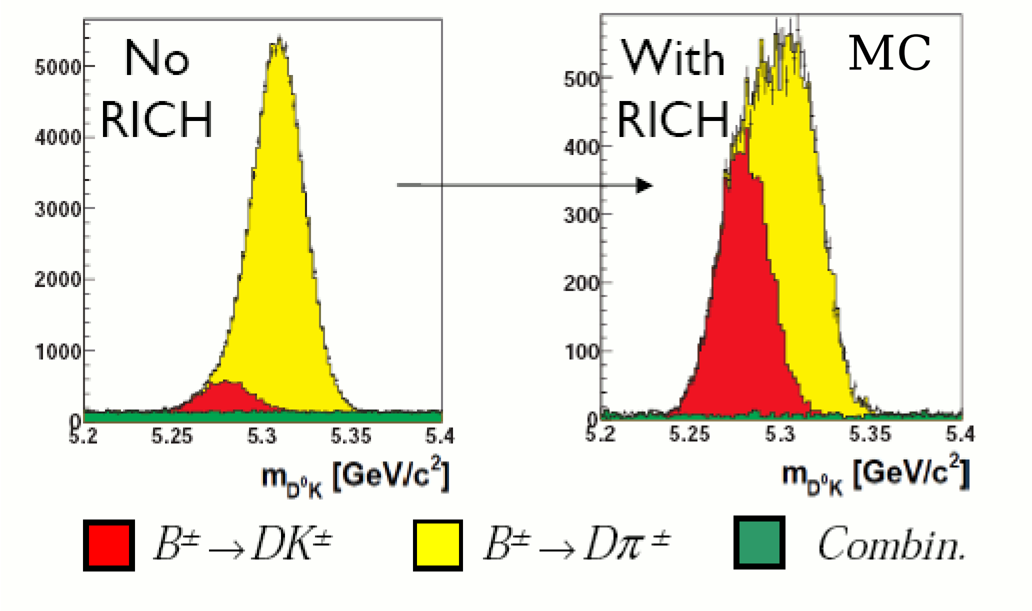


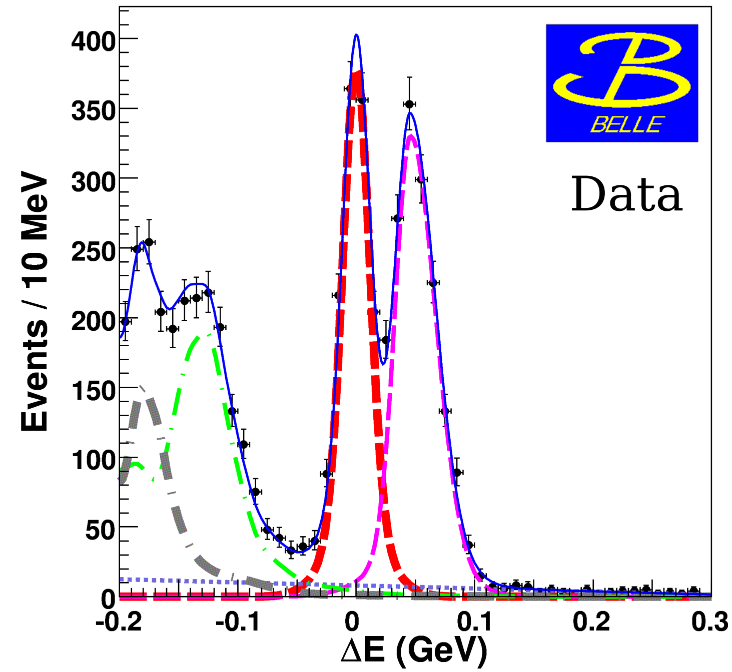
$D_{CP}(\rightarrow \pi^+\pi^-)K$



Predictions for LHCb

PID system (RICH) crucial for LHCb





	LHCb	Belle
Luminosity (fb^{-1})	2	605
$B \to D_{fav} K$ yields	28,000	1,220

→ good benchmark for the sBelle PID system

→ often two kaons in final state: GLW D(KK)K, ADS D(Kπ)K

Predictions for LHCb

GLW (KK, $\pi\pi$), ADS(Kπ) for DK^+

- $K_S\pi^0$ not considered !
- typical statistics for 2 fb^{-1}

Mode	Yield
$B\to D_{sup}K$	650
$B\to D(KK)K$	3,000
$B\to D(\pi\pi)K$	1,000

good estimation for ADS ?
10 vs 1,220
650 vs 28,000
Belle ADS: $q\bar{q}$ background dominates
need to improve continuum rejection

- $\sigma_{\phi_3} \sim (11-14)^\circ$ with $r_B = 0.1$ → **reasonable assumption**
- add ADS mode $D(K3\pi)K \to \sigma_{\phi_3}(B^+) \sim (7-9.5)^\circ$

  determination of $r_D\,(K3\pi)$ possible at CLEOc

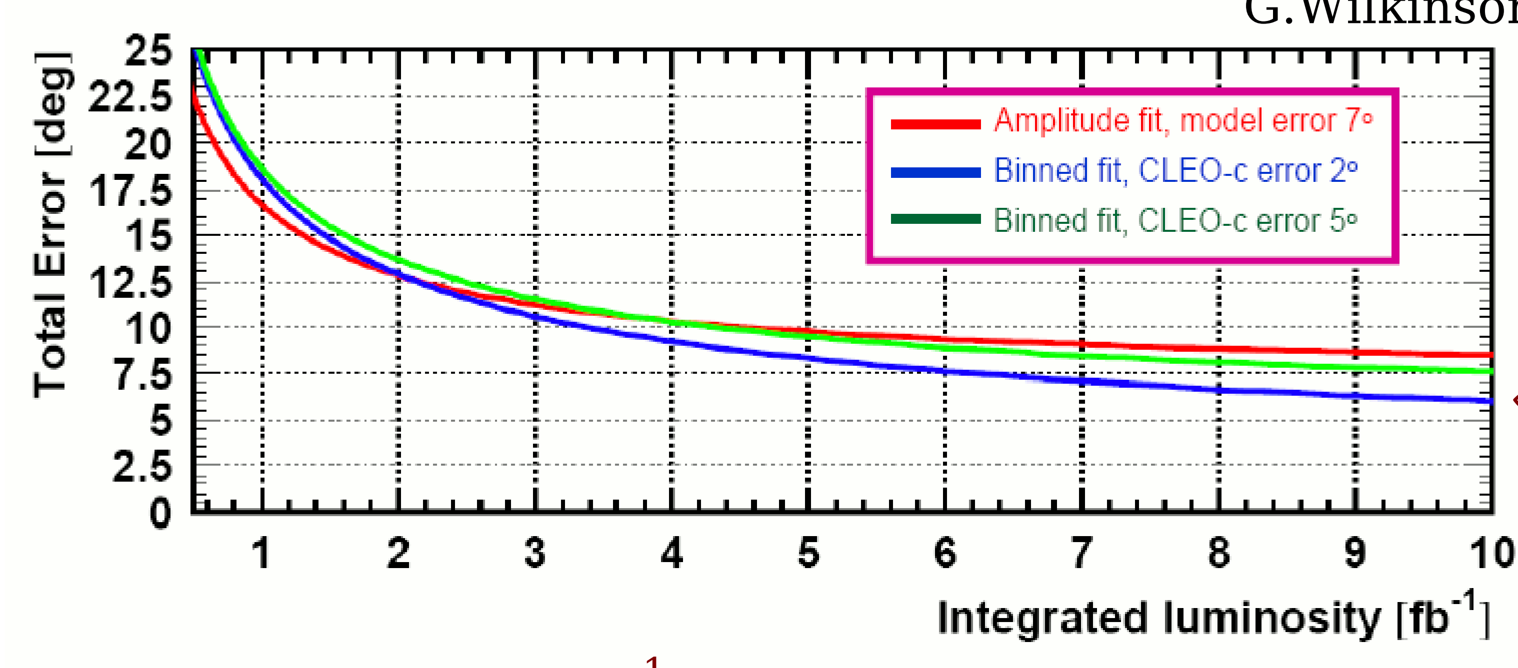
$B^0 \to D(hh)K^{*0}$ sensitivity (2 fb^{-1})

- assumed $r_{B^0} = 0.4$ → **probably too optimistic**
- $\sigma_{\phi_3}(B^0) \sim (5.0-13.0)^\circ$

Predictions for LHCb

Dalitz, $D(K_S \pi\pi)K$

G.Wilkinson, CKM08



⇐

→ 10 fb^{-1} error on ϕ_3 of 6°

including all measurements

3 categories above and time-dep measurements ($B^0 \to D\pi$, $B_s \to D_s K$)

$\sigma(\phi_3) \sim 10^\circ/2\,fb^{-1}$

δ_{B^0} (°)	0	45	90	135	180
σ_γ for 0.5 fb^{-1} (°)	8.1	10.1	9.3	9.5	7.8
σ_γ for 2 fb^{-1} (°)	4.1	5.1	4.8	5.1	3.9
σ_γ for 10 fb^{-1} (°)	2.0	2.7	2.4	2.6	1.9

→ sensitivity to ϕ_3 of LHCb with 10 fb^{-1}: 2−3°

Predictions for sBelle

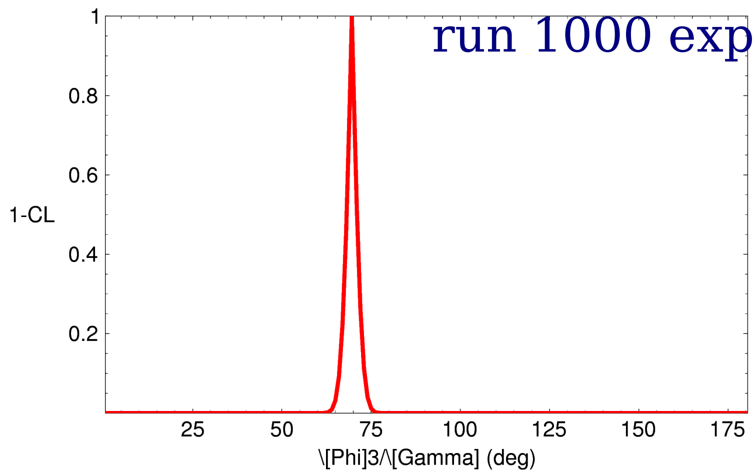
Dalitz, $D(K_S\pi\pi)K$

- unbinned fit: model error: 5° (BaBar), 9° (Belle)
- binned fit (model dependent):
  - with BESIII stat ($\sim 15fb^{-1}$ @ $\psi(3770)$): $\sigma_{x,y} \sim 0.0025$
- experimental syst error (irreducible part): $\sigma_{x,y} \sim 0.003$

F.Martinez-Vidal, CKM08

- stat error:
  - $\sigma_{x,y}(DK) \sim 0.05\sqrt{\frac{0.6}{50}} \sim 0.005$
  - $\sigma_{x,y}(D^*K) \sim 0.12\sqrt{\frac{0.6}{50}} \sim 0.013$
  - $\sigma_{x,y}(DK^*) \sim 0.20\sqrt{\frac{0.3}{50}} \sim 0.016$

assumed $r_B = 0.1$



run 1000 experiments with these assumptions

→ 50 fb^{-1} error on ϕ_3 of 2° using Dalitz modes

GLW+ADS, DK, D^*K, DK^*

- no model error
- experimental syst error (irreducible part): $\sigma_{A,R} \sim 0.01$
  dominated by detector charge asym
- stat error: just scaled

→ 50 fb^{-1} error combining with Dalitz ϕ_3 of 1.5°

Conclusion

- still statistically limited, more modes to be included
- work on the assumptions and limiting factors:

sBelle competitive with LHCb, better than 1° will request more than stat

Backup slides