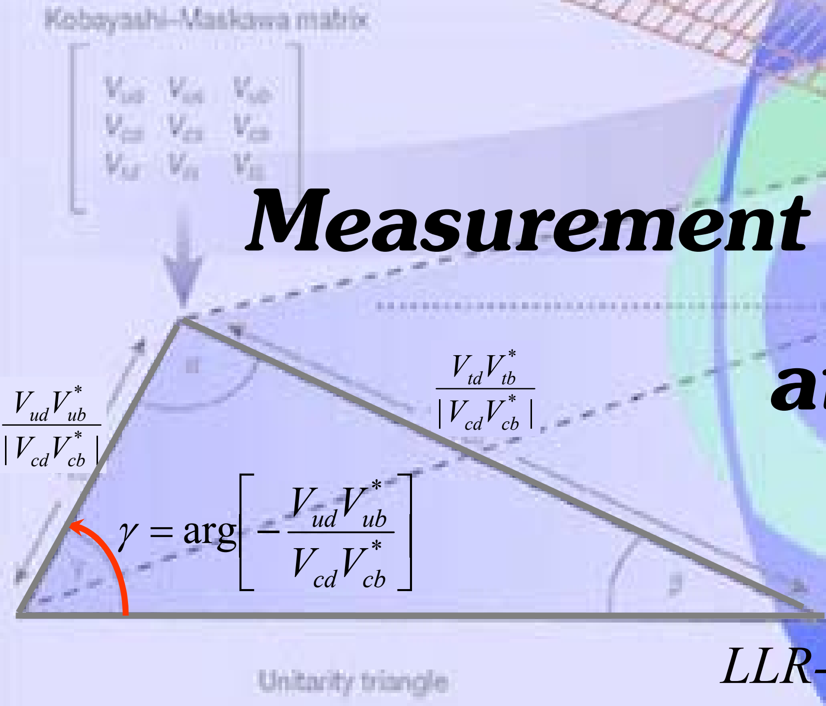
The 2007 Europhysics Conference on High Energy Physics
July 19th-25th, 2007 Manchester, England

LLR École polytechnique

BaBar



Measurement of the CKM angle γ at BaBar

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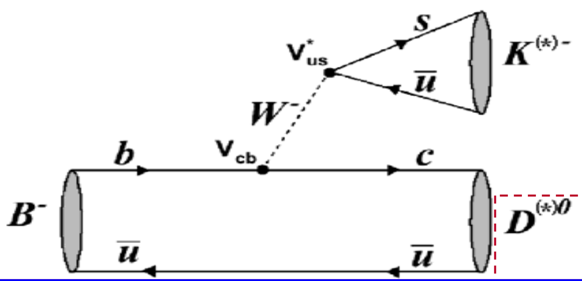
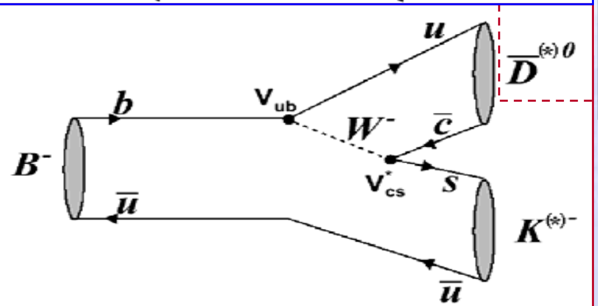
γ *with interferences in* $B^{\pm} \to \tilde{D}^{(*)0} K^{(*)\pm}$

$$A(B^- \to D^{(*)0} K^{(*)-}) \propto V_{cb} V_{us}^* \propto \lambda^3$$





$$A(B^- \to \overline{D}^{(*)0} K^{(*)-}) \propto V_{ub} V_{cs}^* \propto \lambda^3 \sqrt{\bar{\rho}^2 + \bar{\eta}^2}\, e^{i(\delta_B - \gamma)}$$

$\tilde{D}^{(*)0}$= admixture of $D^{(*)0}$ and $\overline{D}^{(*)0}$

3 methods		
GLW	***ADS***	***GGSZ***
CP modes	*Doubly Cabbibo Supp.*	*3 body: Dalitz*
$K^+K^-, \pi^+\pi^-$ *(CP +)*	$D^0 \to K^+\pi^-$	$K_S\pi^+\pi^-$
$K_S\phi$, $K_S\omega$, $K_S\pi^0$ *(CP-)*	$\overline{D}^0 \to K^-\pi^+$	

Theoretically clean: no penguin diagram

+ 3 common unknowns:

- γ, weak phase difference
- δ_B, strong phase difference
- $r_B \equiv \left| \dfrac{A(b \to u)}{A(b \to c)} \right| \sim 0.05 - 0.30$

One set for each D^0K^-, $D^{*0}K^-$, D^0K^{*-}: *resp.* (r_B, δ_B), (r_B^*, δ_B^*), (r_{sB}, δ_{sB})

⇨ **Possibility and need to combine the methods**

Phys.Lett.B253:483-488,1991
Phys.Lett.B265:172-176,1991

GLW *method*

4 observables measured:

CP asymmetries

$$\mathcal{A}_{CP\pm} = \frac{\Gamma(B^- \to D^{(*)0}_{CP\pm} K^{(*)-}) - \Gamma(B^+ \to D^{(*)0}_{CP\pm} K^{(*)+})}{\Gamma(B^- \to D^{(*)0}_{CP\pm} K^{(*)-}) + \Gamma(B^+ \to D^{(*)0}_{CP\pm} K^{(*)+})} = \frac{\pm 2 r^{(*)}_{(s)B} \sin \delta^{(*)}_{(s)B} \sin \gamma}{R_{CP\pm}}$$

Ratio of BFs

$$R_{CP\pm} = \frac{\Gamma(B^- \to D^{(*)0}_{CP\pm} K^{(*)-}) + \Gamma(B^+ \to D^{(*)0}_{CP\pm} K^{(*)+})}{[\Gamma(B^- \to D^{(*)0} K^{(*)-}) + \Gamma(B^- \to D^{(*)0} K^{(*)-})]/2} = 1 + r^{(*)2}_{(s)B} \pm 2 r^{(*)}_{(s)B} \cos \delta^{(*)}_{(s)B} \cos \gamma$$

3 unknowns (γ, δ_B, r_B)

1 constraint : $\mathcal{A}_{CP+} R_{CP+} = -\mathcal{A}_{CP-} R_{CP-}$

Drawbacks of the method

- 8-fold ambiguity on γ
- Small branching fractions ~10^{-6} (including sec. BF)
  ⇨ Statistically limited
- *Main limitation:* $R_{CP+} + R_{CP-} = 2 + r_B^2$: quadratic dependence in r_B
  ⇨ small sensitivity, small *CP* asymmetries

GLW *results*

PRD 73, 051105 (2006)
PRD 72, 071103 (2006)
PRD 71, 031102 (2005)

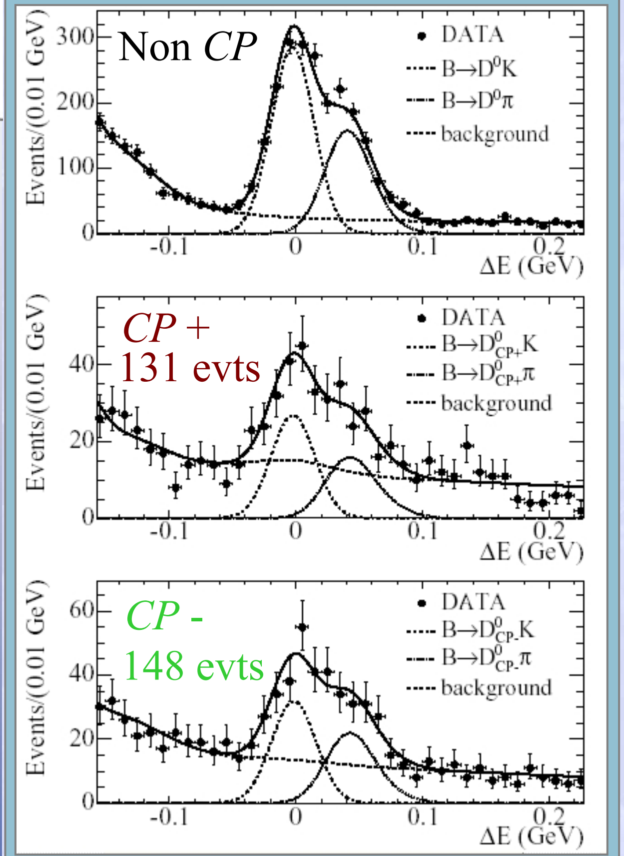
Measuring γ

1. Principle
2. GLW
3. ADS
4. GGSZ

Conclusion

Back-up

$B^{\pm}\rightarrow D^0K^{\pm}$ $(232\times10^6\ B\bar{B})$

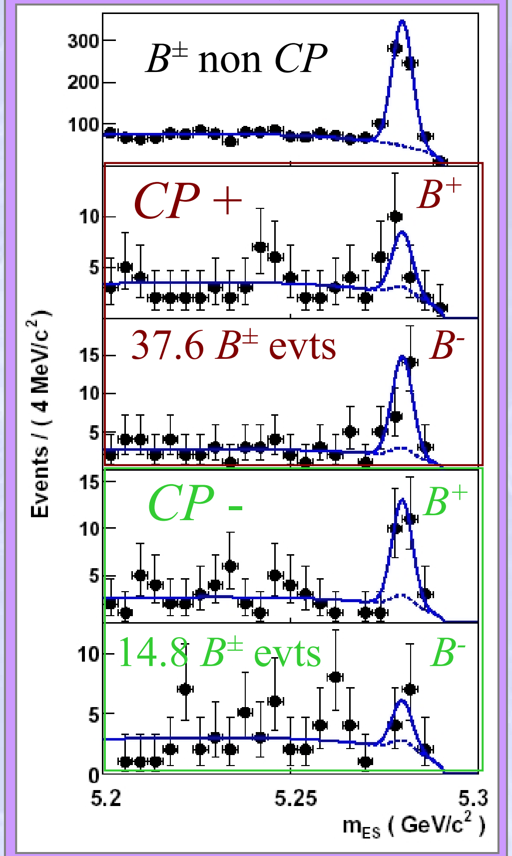


Non CP: $K\pi$

CP+: KK, $\pi\pi$

CP-: $K_s\pi^0$, $K_s\omega$, $K_s\phi$

$B^{\pm}\rightarrow D^0K^{*\pm}$ $(232\times10^6\ B\bar{B})$

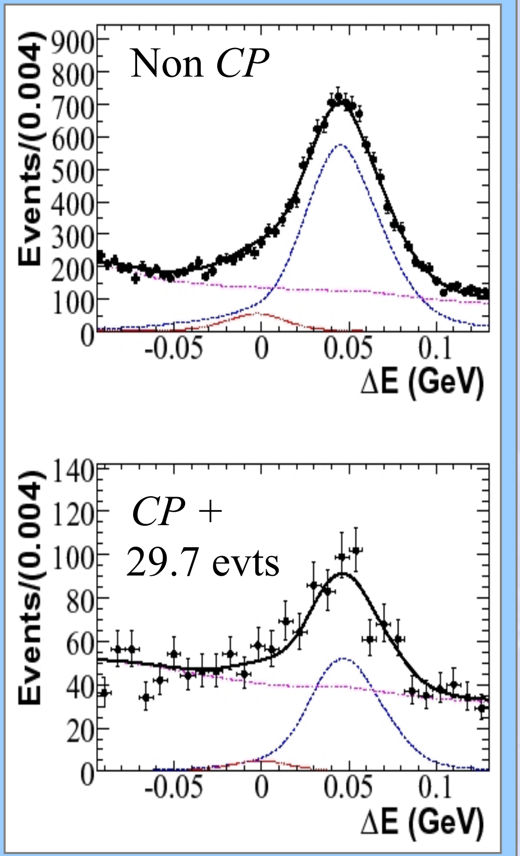


$K^{*-}\rightarrow K_s\pi^-$

Non CP: same as D^*K

CP: same as DK

$B^{\pm}\rightarrow D^{*0}K^{\pm}$ $(124\times10^6\ B\bar{B})$

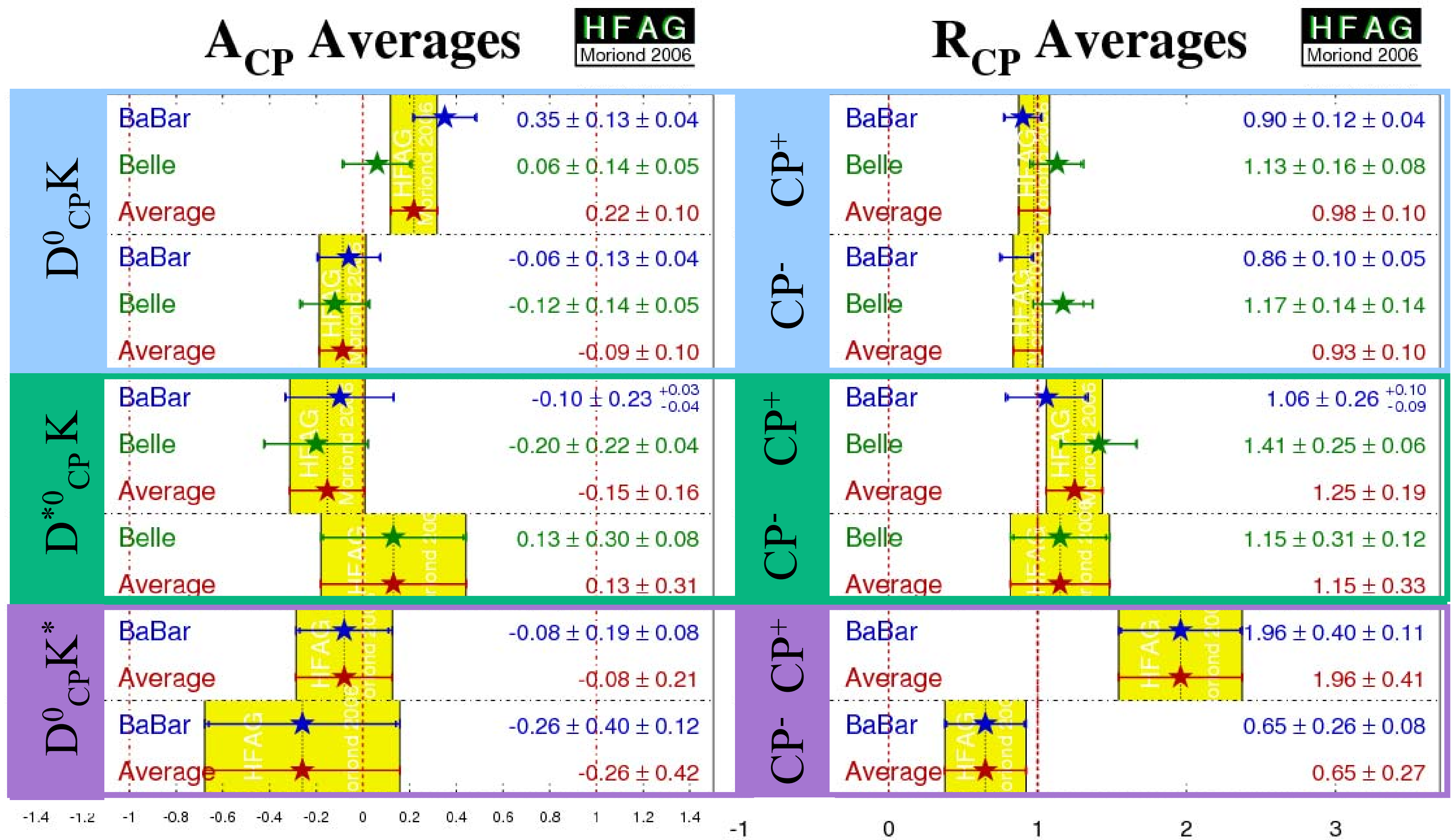


$D^*\rightarrow D^0\pi^0$

Non *CP*: $K\pi$, $K\pi\pi^0$, $K\pi\pi\pi$

CP+: *KK*, $\pi\pi$ (No *CP* -)

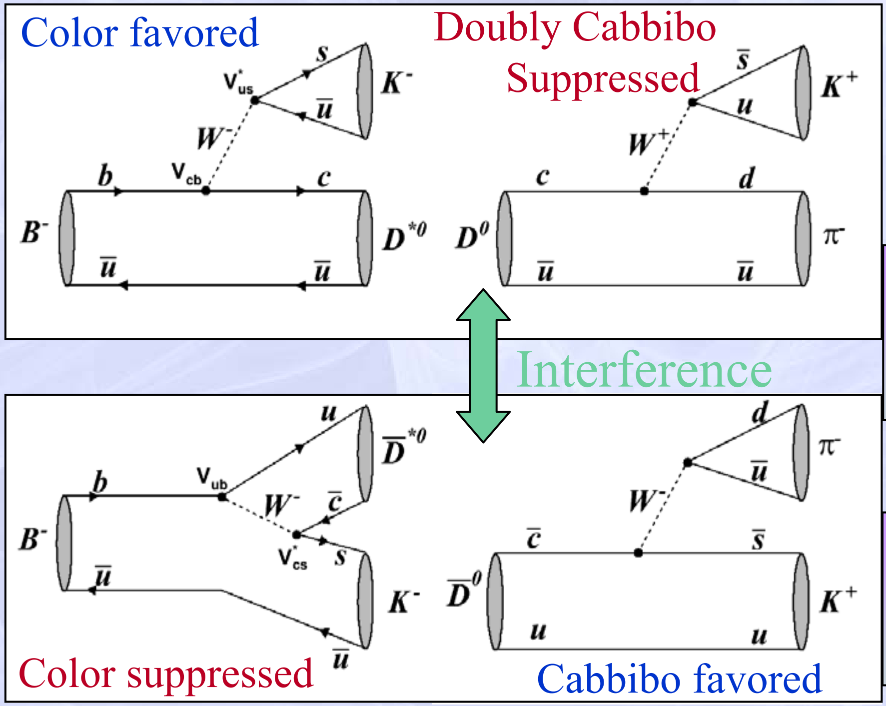
GLW *averages*



- GLW method alone cannot constrain γ alone with current statistics
- But useful when $x_{\pm}$ combined with GGSZ method (see slide 12)

Phys.Rev.Lett. 78 (1997) 3257-3260

ADS *method*



2 observables measured
(4 with D^*K, PRD70,091503(2004))

Ratio of BFs

$$R_{ADS} = \frac{\Gamma(B^- \to D[K^+\pi^-]K^-) + \Gamma(B^+ \to D[K^-\pi^+]K^+)}{\Gamma(B^- \to D[K^-\pi^+]K^-) + \Gamma(B^+ \to D[K^+\pi^-]K^+)}$$
$$= r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D)\cos\gamma$$

CP asymmetries

$$A_{ADS} = \frac{\Gamma(B^- \to D[K^+\pi^-]K^-) - \Gamma(B^+ \to D[K^-\pi^+]K^+)}{\Gamma(B^- \to D[K^+\pi^-]K^-) + \Gamma(B^+ \to D[K^-\pi^+]K^+)}$$
$$= 2 r_B r_D \sin(\delta_B + \delta_D)\sin\gamma / R_{ADS}$$

And 5 unknowns: r_B, r_D, δ_B, δ_D, γ

$$r_D^2 \equiv \left|\frac{A(D \to K^+\pi^-)}{A(D \to K^-\pi^+)}\right|^2 = (0.365 \pm 0.021)\%$$
PLB 592,1 (PDG 2004)

D decay strong phase

Scan all possible values

- Main limitation: small BF ~10^{-6}
- Good senstivity to r_B^2 with R_{ADS}
- But amplitudes comparable ⇨ Larger *CP* violation

PRD 72, 032004 (2005)
PRD 73, 071104 (2006)

$232 \times 10^6 \, B\bar{B}$

ADS *results*

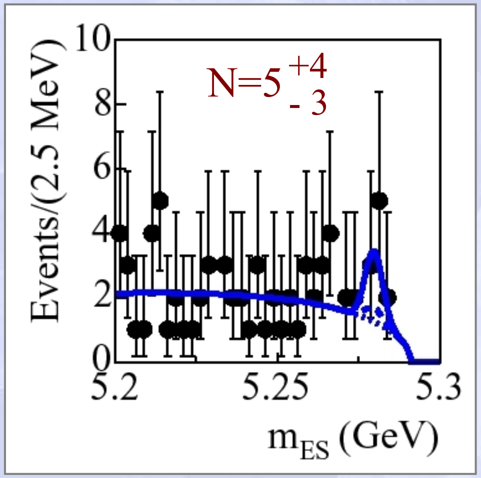
Measuring γ

1. Principle
2. GLW
3. ADS
4. GGSZ

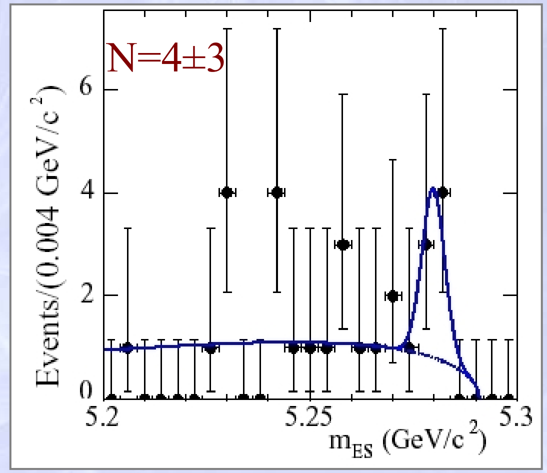
Conclusion

Back-up

$B^{\pm} \to D^0 K^{\pm}$

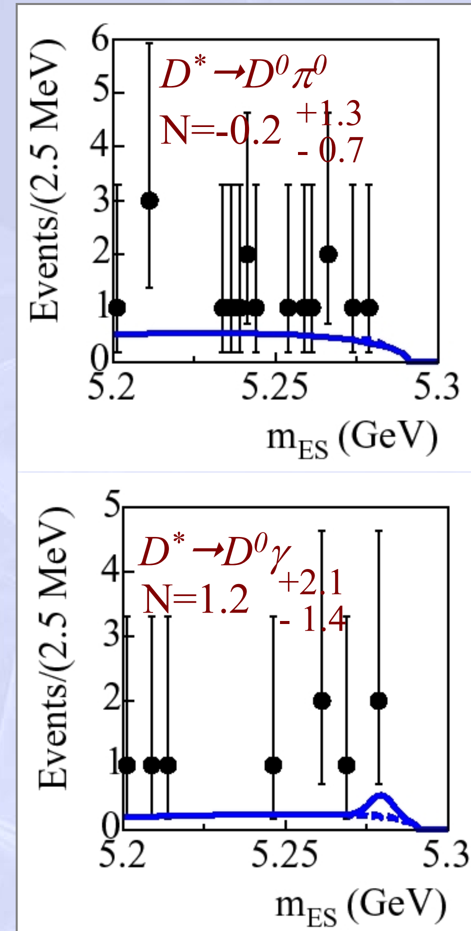


$B^{\pm} \to D^0 K^{*\pm}$



No significant signal

$B^{\pm} \to D^{*0} K^{\pm}$



Only bayesian limits (90% CL) on R_{ADS} and $r^{(*)}_{(s)B}$

	R_{ADS}	r_B
D^0K	<0.029	r_B<0.23
$D^{*0}K$	<0.023 ($D^0\pi^0$) <0.045 ($D^0\gamma$)	$(r_B^*)^2$<$(0.16)^2$
D^0K^*	0.046±0.032	r_{sB}=0.20±0.14

hep-ex/0607065
$226\times10^6\ B\bar{B}$

ADS *results:* $B^- \to [K^+\pi^-\pi^0]_D K^-$

Preliminary

- Similar to classic ADS analysis with DCS $D^0 \to K^+\pi^-$
  - Complication: $(|A_D|, \delta_D)$ varying in the Dalitz plane

$$R_{ADS} = \frac{\Gamma(B^- \to D[K^+\pi^-]K^-) + \Gamma(B^+ \to D[K^-\pi^+]K^+)}{\Gamma(B^- \to D[K^-\pi^+]K^-) + \Gamma(B^+ \to D[K^+\pi^-]K^+)} = r_B^2 + r_D^2 + 2r_B r_D C\cos\gamma$$

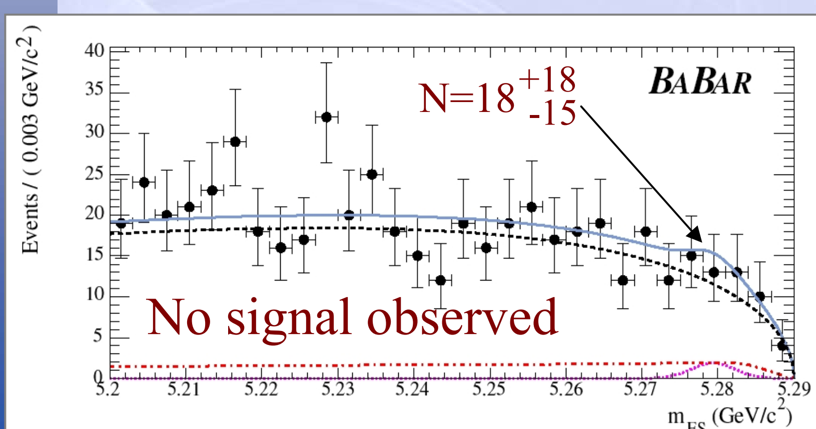
$$A_{ADS} = \frac{\Gamma(B^- \to D[K^+\pi^-]K^-) - \Gamma(B^+ \to D[K^-\pi^+]K^+)}{\Gamma(B^- \to D[K^+\pi^-]K^-) + \Gamma(B^+ \to D[K^-\pi^+]K^+)} = 2r_B r_D S\sin\gamma / R_{ADS}$$

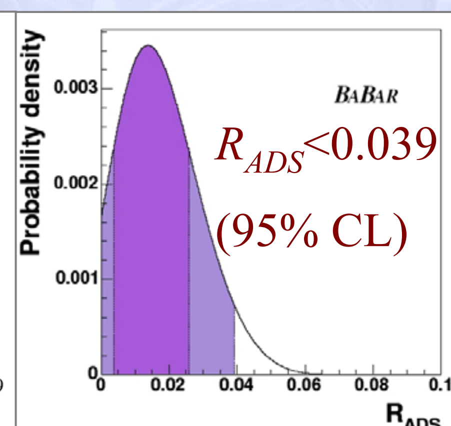
  - Smaller r_D=(0.214±0.011)% ⇨ better sensitivity on r_B
  - C unknown: |C|≤1
  - More background, but higher BF's

$$C = \frac{\int A_D(\vec{s})\bar{A}_D(\vec{s})\cos(\delta_D(\vec{s}) + \delta_B(\vec{s}))d\vec{s}}{\sqrt{\int |A_D(\vec{s})|^2 d\vec{s}}\sqrt{\int |\bar{A}_D(\vec{s})|^2 d\vec{s}}}$$

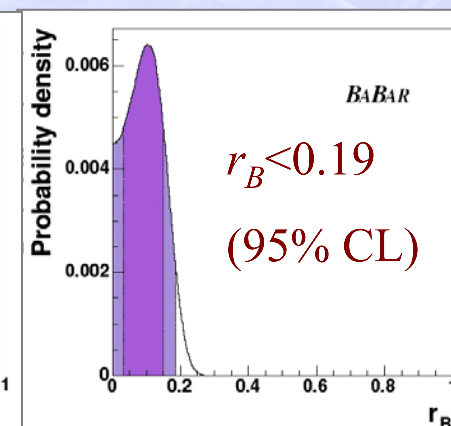
$$S = \frac{\int A_D(\vec{s})\bar{A}_D(\vec{s})\sin(\delta_D(\vec{s}) + \delta_B(\vec{s}))d\vec{s}}{\sqrt{\int |A_D(\vec{s})|^2 d\vec{s}}\sqrt{\int |\bar{A}_D(\vec{s})|^2 d\vec{s}}}$$

$$\vec{s} = (m^2_{K\pi}, m^2_{K\pi^0})$$





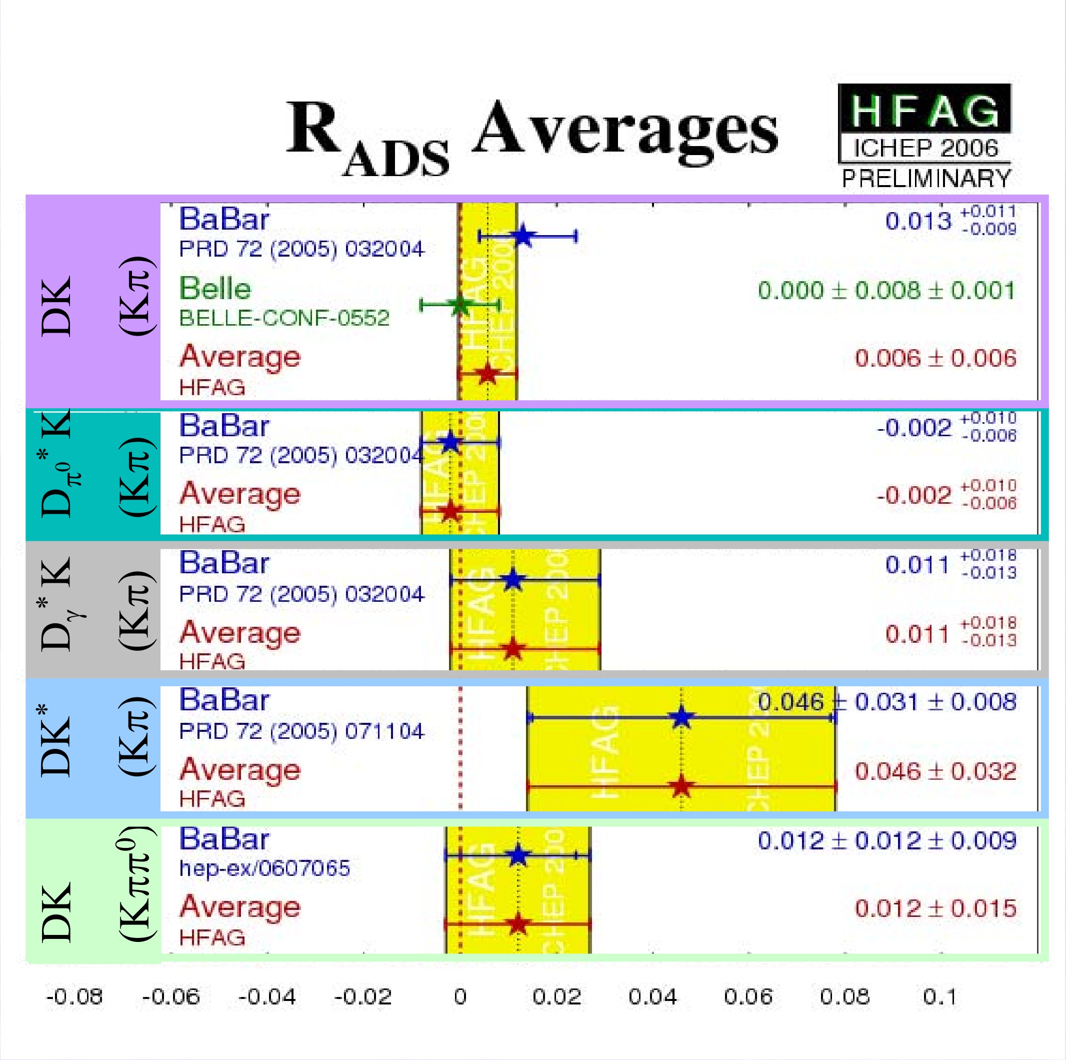
Experimental LH



Bayesian LH

Measuring γ
1. Principle
2. GLW
3. ADS
4. GGSZ
Conclusion
Back-up

ADS *averages*



- Not possible to constrain $r^{(*)}_{(s)B}$ with R_{ADS} measurements alone
- $r^{(*)}_{(s)B}$ smaller than expected
- A_{ADS} not measured

Measuring γ

1. Principle
2. GLW
3. ADS
4. GGSZ

Conclusion

Back-up

Phys.Rev. D68 (2003) 054018

Dalitz GGSZ: $B^- \to D^{(*)}{}_{K_S\pi^+\pi^-} K^{(*)-}$

- $D^0 \to K_S\pi^+\pi^-$ final state accessible through many decays: Dalitz analysis

$$\mathcal{A}_{B^-}(m^2_{K_S\pi^-}, m^2_{K_S\pi^+}) = \mathcal{A}_D(m^2_{K_S\pi^-}, m^2_{K_S\pi^+}) + \kappa\, r^{(*)}_{(s)B}\, e^{i(\delta^{(*)}_{(s)B}-\gamma)}\, \mathcal{A}_D(m^2_{K_S\pi^+}, m^2_{K_S\pi^-})$$

$$\mathcal{A}_{B^+}(m^2_{K_S\pi^+}, m^2_{K_S\pi^-}) = \mathcal{A}_D(m^2_{K_S\pi^+}, m^2_{K_S\pi^-}) + \kappa\, r^{(*)}_{(s)B}\, e^{i(\delta^{(*)}_{(s)B}+\gamma)}\, \mathcal{A}_D(m^2_{K_S\pi^-}, m^2_{K_S\pi^+})$$

DK^- $\kappa=+1$

DK^{*-} Interference with $B^\pm \to D(K_S\pi^\pm)_{\text{non-}K^*}$

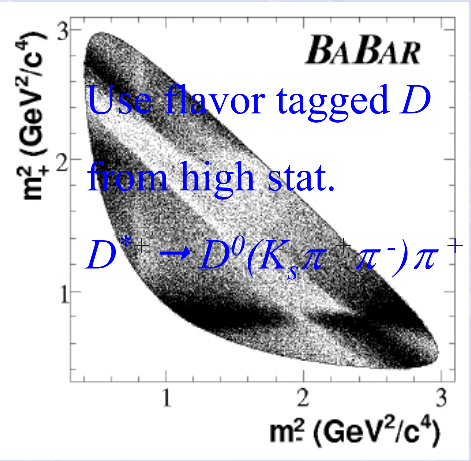
$0 \le \kappa \le 1$ If interference $\to 0$: $\kappa \to 1$

$r_{sB} \to r_B$

$\delta_{sB} \to \delta_B$

D^*K^- $\kappa=+1$ for $D^{*0} \to D^0\pi$

$\kappa=-1$ for $D^{*0} \to D^0\gamma$



Purity: 97.7%

Same strategy for all analyses:

1- Fit the amplitude $\mathcal{A}_D$

2- Fit of the $B^- \to D^{(*)}[K_s\pi^+\pi^-]\, K^{(*)-}$ Dalitz plot

⇨ *CP* parameters

3- Obtain CL on observables $r_{(s)B}{}^{(*)}$, $\delta_{(s)B}{}^{(*)}$, γ

2-fold ambiguity: $(\gamma, \delta_B) \to (\gamma+\pi, \delta_B+\pi)$

GGSZ: $[K_s\pi^+\pi^-]_D$ *Dalitz model*

<u>*Breit-Wigner model:*</u>

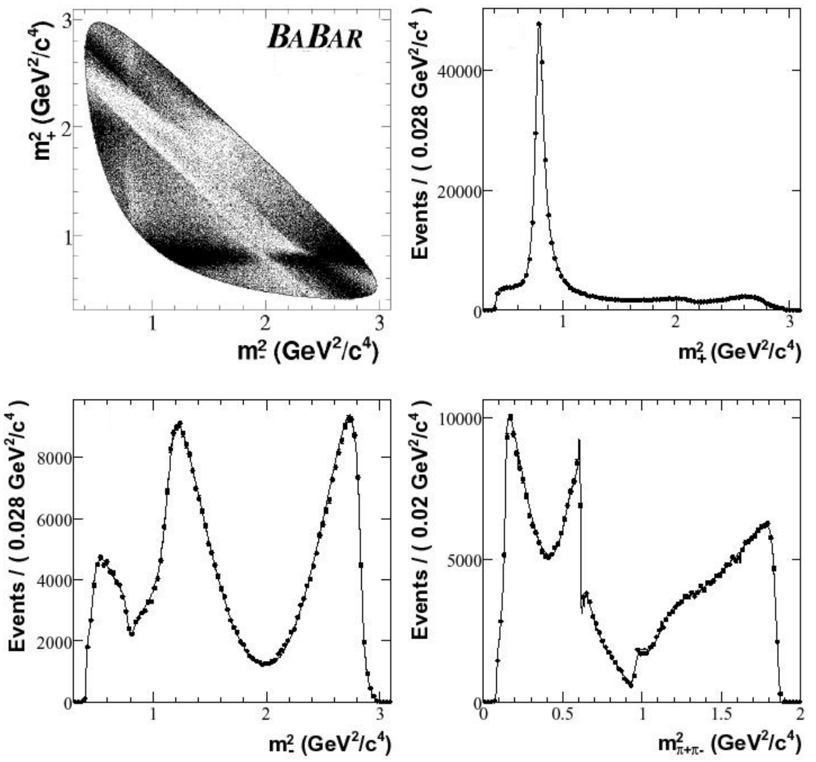
$$\mathcal{A}_D(m_-^2, m_+^2) = \sum_r a_r e^{i\phi_r} \mathcal{A}_r(m_-^2, m_+^2) + a_{NR} e^{i\phi_{NR}}$$

16 Resonances

Non Resonant term

Total=119.5% (due to interferences)

Component	$Re\{a_r e^{i\phi_r}\}$	$Im\{a_r e^{i\phi_r}\}$	Fit fraction (%)	
$K^*(892)^-$	-1.223 ± 0.011	1.3461 ± 0.0096	58.1	$K\pi$
$K_0^*(1430)^-$	-1.698 ± 0.022	-0.576 ± 0.024	6.7	
$K_2^*(1430)^-$	-0.834 ± 0.021	0.931 ± 0.022	3.6	
$K^*(1410)^-$	-0.248 ± 0.038	-0.108 ± 0.031	0.1	
$K^*(1680)^-$	-1.285 ± 0.014	0.205 ± 0.013	0.6	
$K^*(892)^+$	0.0997 ± 0.0036	-0.1271 ± 0.0034	0.5	
$K_0^*(1430)^+$	-0.027 ± 0.016	-0.076 ± 0.017	0.0	
$K_2^*(1430)^+$	0.019 ± 0.017	0.177 ± 0.018	0.1	
$\rho(770)$	1	0	21.6	$\pi\pi$ P,D
$\omega(782)$	-0.02194 ± 0.00099	0.03942 ± 0.00066	0.7	
$f_2(1270)$	-0.699 ± 0.018	0.387 ± 0.018	2.1	
$\rho(1450)$	0.253 ± 0.038	0.036 ± 0.055	0.1	
Non-resonant	-0.99 ± 0.19	3.82 ± 0.13	8.5	
$f_0(980)$	0.4465 ± 0.0057	0.2572 ± 0.0081	6.4	$\pi\pi$ S
$f_0(1370)$	0.95 ± 0.11	-1.619 ± 0.011	2.0	
σ	1.28 ± 0.02	0.273 ± 0.024	7.6	
σ'	0.290 ± 0.010	-0.0655 ± 0.0098	0.9	



Not well-established:

- mass and width fitted
- give better description of data

Model systematic uncertainty: comparison with alternative model ($\pi\pi$ S-wave K-matrix)

GGSZ *results:* $(x_\pm, y_\pm)$

- At low statistics and low r_B values, use of cartesian coordinates:
  - Unbiased and Gaussian
  - Not the case for $(\gamma, \delta_{(S)B}^{(*)}, r_{(S)B}^{(*)})$

$$x_{(s)\pm}^{(*)} = Re\left(r_{(s)B}^{(*)} e^{i(\delta_{(s)B}^{(*)} \pm \gamma)}\right)$$
$$y_{(s)\pm}^{(*)} = Im\left(r_{(s)B}^{(*)} e^{i(\delta_{(s)B}^{(*)} \pm \gamma)}\right)$$

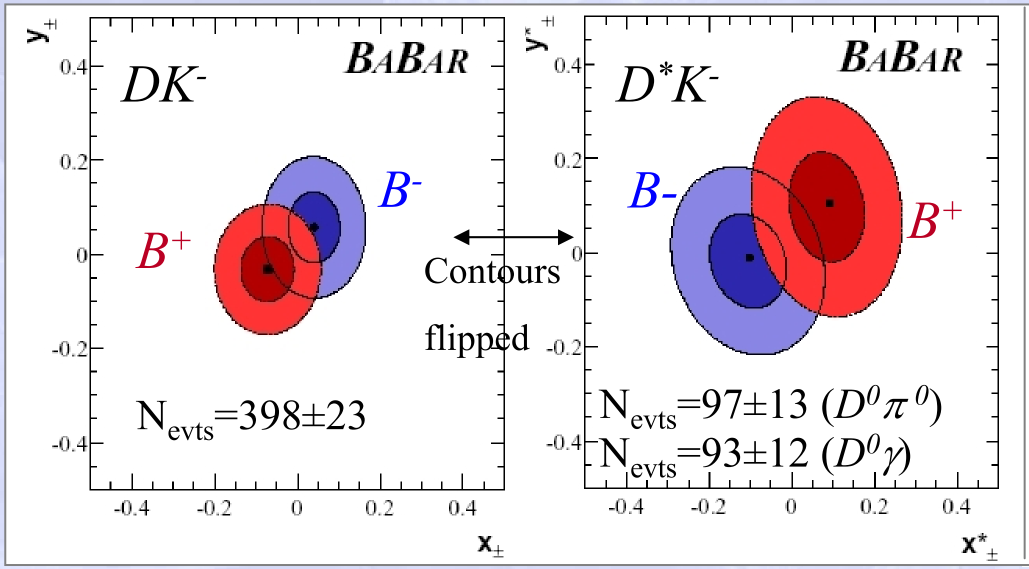
$$\Rightarrow x_{(s)\pm}^{(*)2} + y_{(s)\pm}^{(*)2} = r_{(s)B}^{(*)2}$$

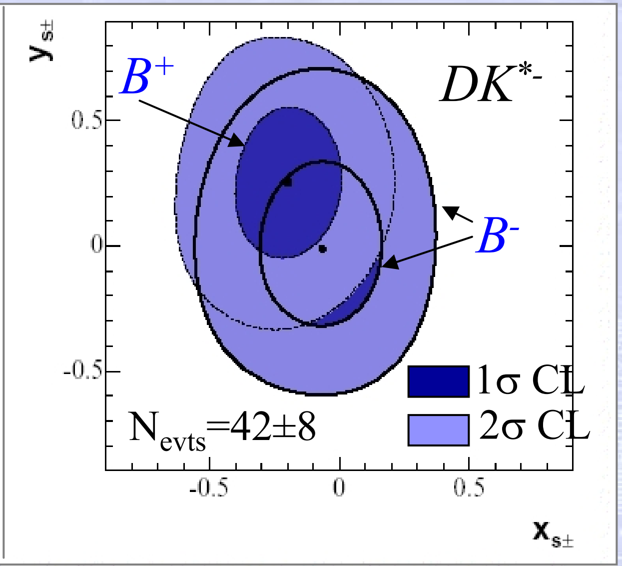
hep-ex/0607104
$347 \times 10^6 \, B\bar{B}$

1σ CL

2σ CL

hep-ex/0507101
$227 \times 10^6 \, B\bar{B}$





GLW DK		DK*
x_+: 0.102±0.062±0.022	GLW Competitive!	x_+: 0.32±0.18±0.07
x_-:-0.12±0.08±0.03		x_-:-0.33±0.16±0.06

Measuring γ

1. Principle
2. GLW
3. ADS
4. GGSZ

Conclusion

Back-up

GGSZ *results:* γ

- From fitted *CP* parameters $(x_\pm, y_\pm)$, $(x_\pm^*, y_\pm^*)$, $(x_{S\pm}, y_{S\pm})$:
  - use a nD Neyman Confidence Region approach (frequentist)
  - Extract $(r_B, r_B, \kappa . r_{SB}^*)$, $(\delta_B, \delta_B^*, \delta_{SB})$, γ

hep-ex/0607104

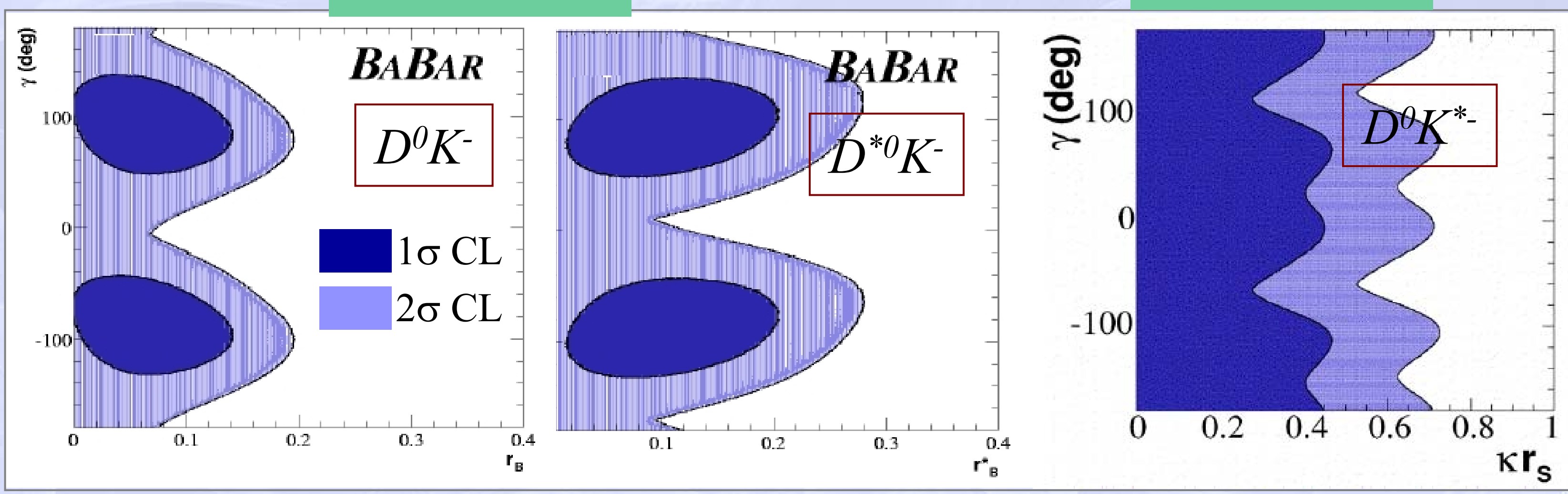
$347\times10^6\ B\bar{B}$

5D CR

hep-ex/0507101

$227\times10^6\ B\bar{B}$

3D CR



γ [mod π]=$(92\pm41\pm11\pm12)°$ (2-fold ambiguity)

$r_B<0.142$

$r_B^*\in[0.016;0.206]$ Smaller than 2005 analysis

No 1σ limit on γ with DK^* alone

$\kappa . r_{SB}<0.5$

Measuring γ

1. Principle
2. GLW
3. ADS
4. GGSZ

Conclusion

Back-up

Dalitz GGSZ: $B^- \to D_{\pi^+\pi^-\pi^0} K^-$

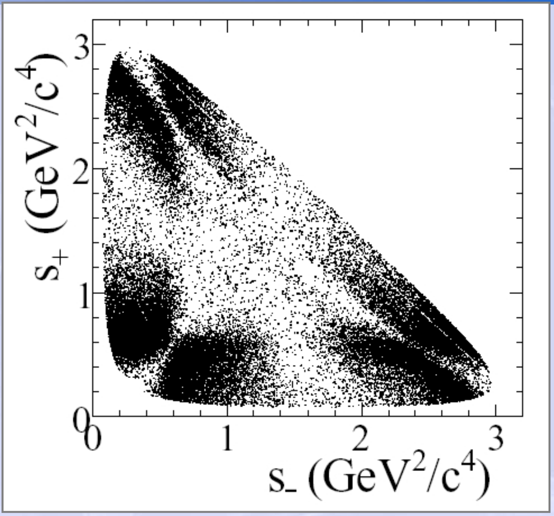
- Compared to $B^\pm \to [K_S\pi^+\pi^-]_D K^\pm$:
  - Different Dalitz structure (15 resonances)
  - Larger backgrounds

- Non linear correlations with (r_B, δ_B, γ) and cartesian coordinates

  ⇨ use of polar coordinates

$$\rho_\pm \equiv \sqrt{(x_\pm - x^0)^2 + y_\pm^2} \qquad \theta_\pm \equiv \arctan\left(\frac{y_\pm}{x_\pm - x^0}\right)$$

$$x^0 \equiv \int A_D(m_-, m_+)\overline{A}_D(m_-, m_+)dm^- dm^+ = 0.85$$



N=170 ± 29 events

$$\boxed{\begin{aligned} \rho_+ &= 0.75 \pm 0.11 \pm 0.06 \\ \rho_- &= 0.72 \pm 0.11 \pm 0.06 \\ \theta_+ &= (147 \pm 23 \pm 13)^\circ \\ \theta_- &= (173 \pm 42 \pm 19)^\circ \end{aligned}}$$

ρ_+/ρ_- corr. =14%

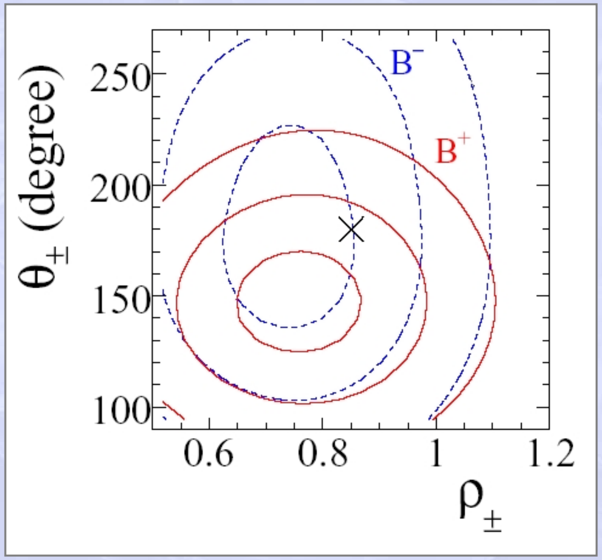
other corr. < 1%

Systematics mostly from Dalitz model

Errors on:

- $\theta_\pm$: too large to determine γ
- $\rho_\pm$: small enough to be useful

Contours of constant $\mathcal{L}$: 1σ, 2σ, 3 σ



Measuring γ

1. Principle
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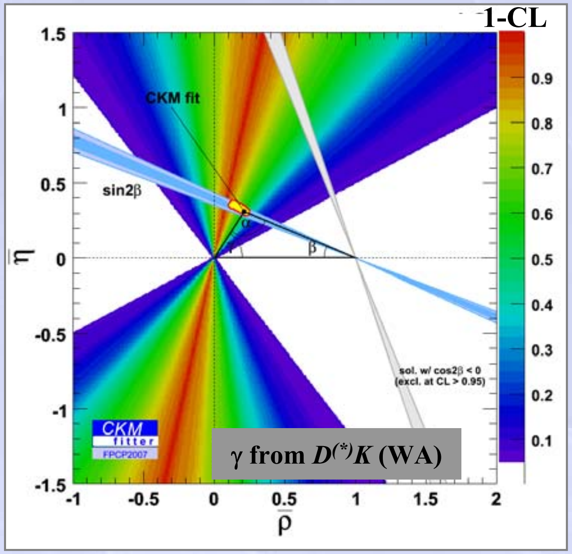
Conclusion

Back-up

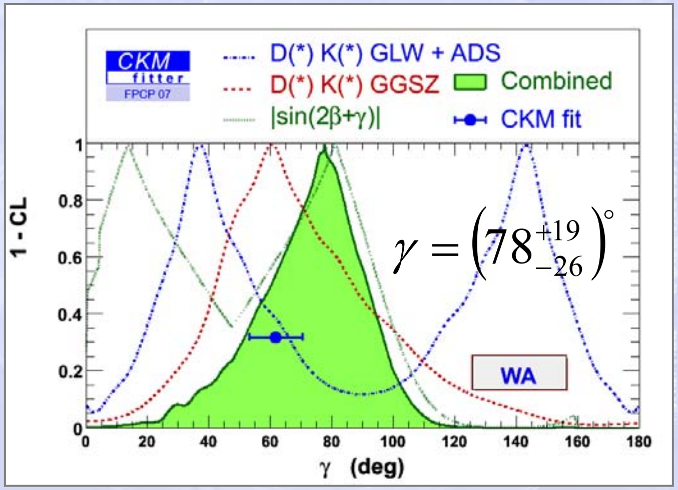
Conclusion and perspectives

- γ is a difficult measurement: deemed impossible a few years ago



Courtesy of V. Tisserand

- The direct path to γ : charged *B* decays
  - 3 theoretically clean methods
  - Dalitz method is the most powerful so far
  - GLW has competitive errors on $x_{\pm}$: improves constraints when combined
  - Only part of the statistics available used: need to update analyses
  - At high stat.: will need a model independent Dalitz to avoid model syst.



Courtesy of V. Tisserand

- The indirect path to γ: neutral *B* decays
  - Helps in constraining
  - But need input for $r^{(*)}$, and stat. limited

- A long way ahead

Back-up slides

The BaBar experiment

Measuring γ

1. Principle
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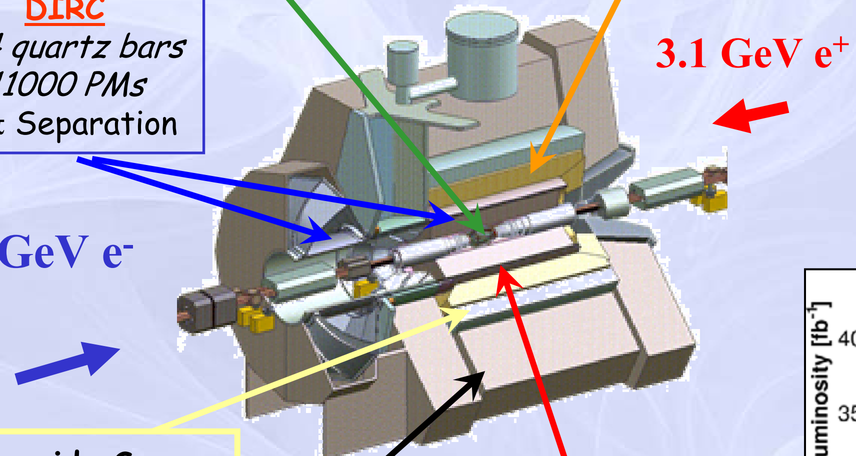
Conclusion

Back-up

SVT
Silicon Vertex Tracker
5 layers, double sided
Precise Δz measurement p

EMC
EM Calorimeter
6580 CsI(Tl) crystals
Good E resolution π^0, γ
(Eγ > 30MeV)

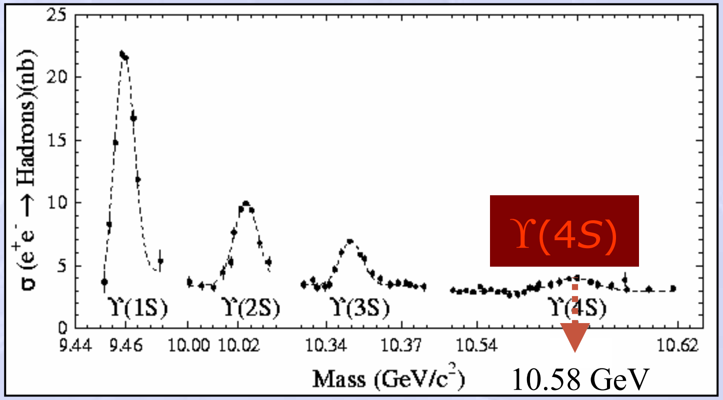
DIRC
144 quartz bars
11000 PMs
K/π Separation



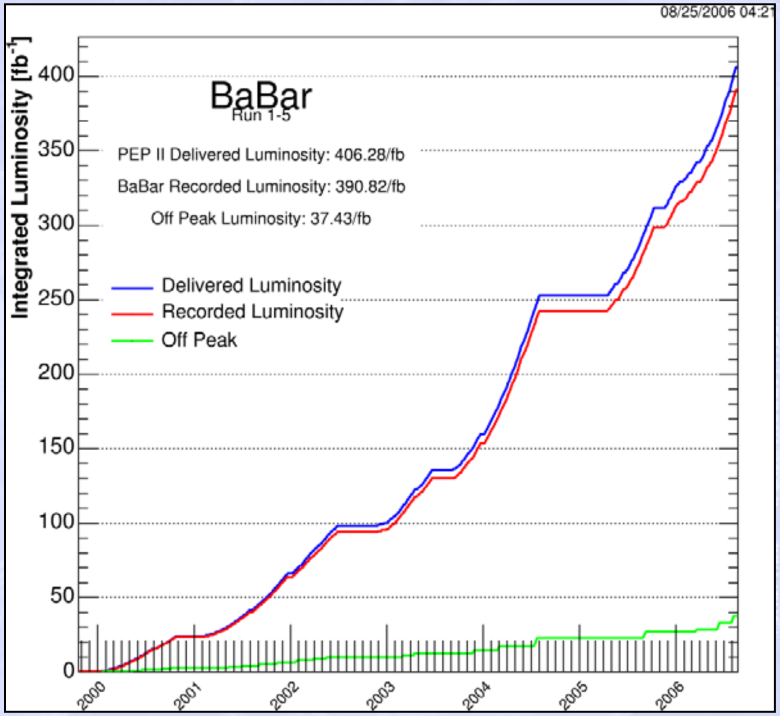
Solenoide Supra
1.5 T

DCH
Drift Chamber
40 layers
Good p resolution
K/π Separation(dE/dx)

IFR
Instrumented Flux Return
Iron / Resistive Plate Chambers
/ Limited Streamer Tubes
muon / neutral hadrons id



$B\bar{B}$ threshold



Common analysis techniques

Measuring γ

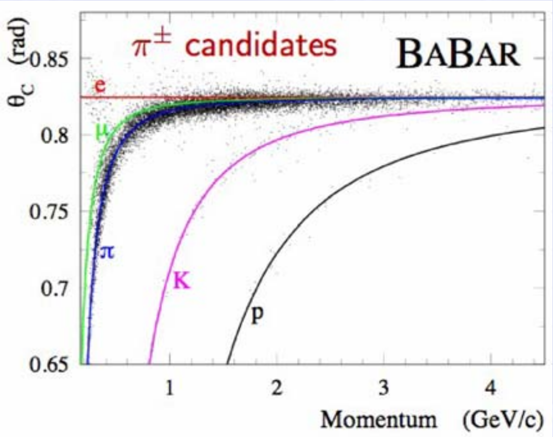
1. Principle
2. GLW
3. ADS
4. GGSZ

Conclusion

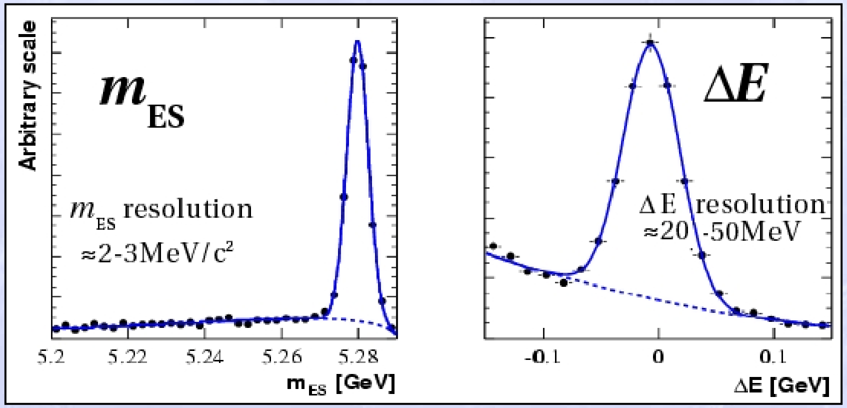
Back-up

Reconstruction

- Cut on geometric variable (polar angles)
  - ***Reduce combinatorics*** *from low momentum π*
  - *Eliminate quickly varying acceptance region*
- PID requirements
  - *Combine info from SVT, DCH, DIRC*
  - *Provide **K/π separation***
- **Best *B* candidate** selected with χ^2 on different variables



Signal identification



Beam energy substituted mass

$$m_{ES} = \sqrt{\left(\frac{s}{2} + \vec{p}_0 \cdot \vec{p}_B\right)^2 / E_0^{*2} - \vec{p}_B^{\,2}}$$

B energy in CM frame

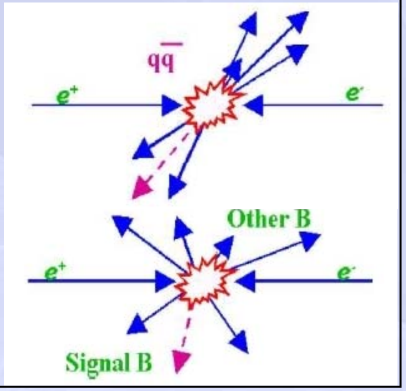
$$\Delta E = E_B^* - \frac{\sqrt{s}}{2}$$

Requires mass hyp.

Common analysis techniques

Background fighting

- **$q\bar{q}$ rejection**: *uses difference of topology between* ***spherical B*** *decays and* ***jet-like*** *continuum*
  - *Cuts on |cosThetaT| (<0.9 typically)*
  - *Fisher, NN: L_0, L_2, $\cos\theta_{Bmom}$, $\cos\theta_{Bthrust}$*



- **$B\bar{B}$ rejection**: *accounted for in the fit*

Fit: Extended unbinned maximum Likelihood fit

$$\underbrace{L = \frac{\exp\left(-\sum_j n_j\right)}{N!}}_{\text{Poisson term}} \prod_{i=1}^{N} \left(\sum_j n_i P_j^i \right) \longrightarrow P_j^i = \prod_{k=1}^{N_{\mathrm{var}}} P_j\,(\theta_k^i)$$

Fit variable: m_{ES}, ΔE, $\mathcal{F}$, …

$$\Rightarrow BF = \frac{n_{meas.} - n_{biais}}{n_B \varepsilon}$$

$$\mathcal{A}_{CP} = \frac{BF(B \to X) - BF(\bar{B} \to \bar{X})}{BF(B \to X) + BF(\bar{B} \to \bar{X})}$$

GGSZ: $[\pi\pi\pi^0]_D$ Dalitz model

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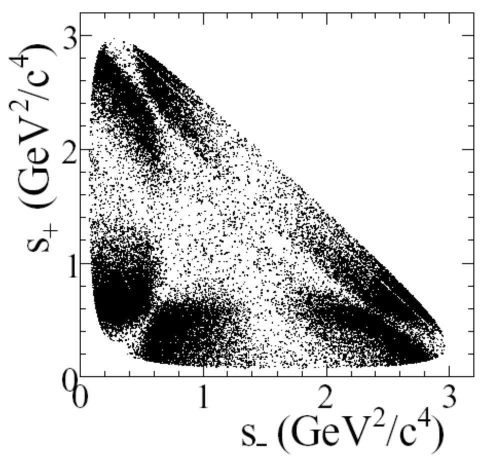
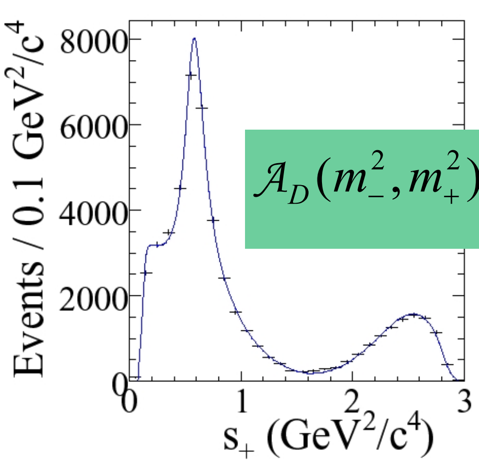
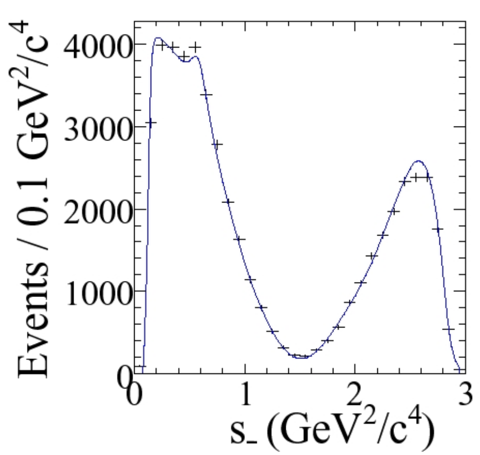






$$D^0 \to r + C$$
$$\hookrightarrow A+B$$

$$\mathcal{A}_D(m_-^2, m_+^2) = \sum_r a_r e^{i\phi_r} \mathcal{A}_r(m_-^2, m_+^2) + a_{NR} e^{i\phi_{NR}}$$

$$\mathcal{A}_r = \frac{\boxed{F_r F_s}}{m_r - M_{AB} - i m_r \Gamma(M_{AB})}$$

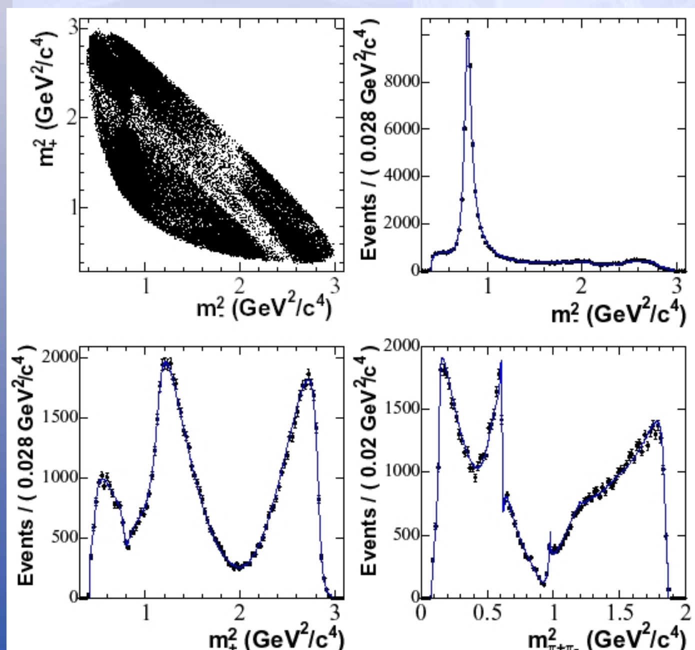
Spin dep.
Form Factors

State	R_r (%)	$\Delta\phi_r$ (°)	f_r(%)
$\rho^+(770)$	100	0	67.8±0.0±0.6
$\rho^0(770)$	58.8±0.6±0.2	16.2±0.6±0.4	26.2±0.5±1.1
$\rho^-(770)$	71.4±0.8±0.3	−2.0±0.6±0.6	34.6±0.8±0.3
$\rho^+(1450)$	21±6±13	−146±18±24	0.11±0.07±0.12
$\rho^0(1450)$	33±6±4	10±8±13	0.30±0.11±0.07
$\rho^-(1450)$	82±5±4	16±3±3	1.79±0.22±0.12
$\rho^+(1700)$	225±18±14	−17±2±3	4.1±0.7±0.7
$\rho^0(1700)$	251±15±13	−17±2±2	5.0±0.6±1.0
$\rho^-(1700)$	200±11±7	−50±3±3	3.2±0.4±0.6
$f_0(980)$	1.50±0.12±0.17	−59±5±4	0.25±0.04±0.04
$f_0(1370)$	6.3±0.9±0.9	156±9±6	0.37±0.11±0.09
$f_0(1500)$	5.8±0.6±0.6	12±9±4	0.39±0.08±0.07
$f_0(1710)$	11.2±1.4±1.7	51±8±7	0.31±0.07±0.08
$f_2(1270)$	104±3±21	−171±3±4	1.32±0.08±0.10
$\sigma(400)$	6.9±0.6±1.2	8±4±8	0.82±0.10±0.10
Non-Res	57±7±8	−11±4±2	0.84±0.21±0.12

ππ S-wave K-matrix model

- Purpose: describe ππ S-wave
- Motivation: better description of dynamics than BW model in the presence of overlapping resonances
- No improvement in the χ^2 test, since dominated by P-wave components, identical in the two models

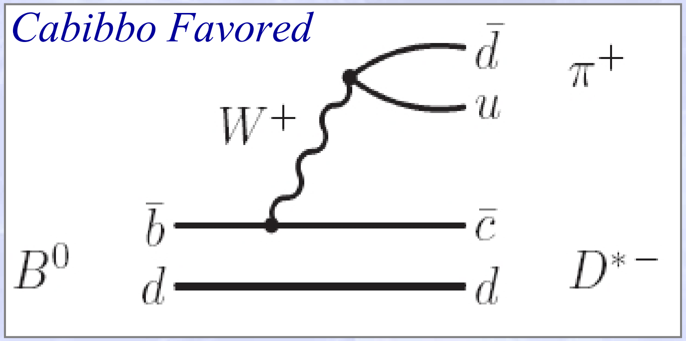
$\chi^2/n_{DOF}=1.27$



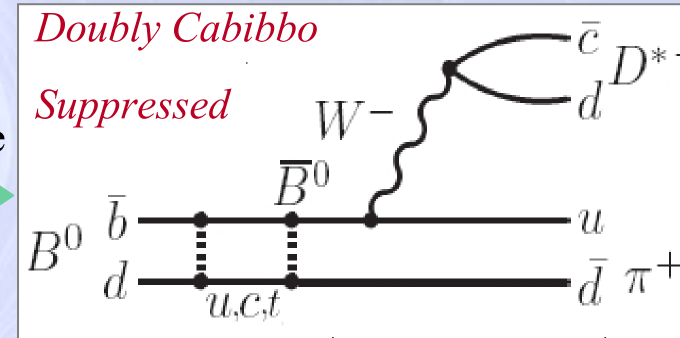
Component	$\mathrm{Re}\{a_r e^{i\phi_r}\}$	$\mathrm{Im}\{a_r e^{i\phi_r}\}$	Fit fraction (%)
$K^*(892)^-$	-1.159 ± 0.022	1.361 ± 0.020	58.9
$K_0^*(1430)^-$	2.482 ± 0.075	-0.653 ± 0.073	9.1
$K_2^*(1430)^-$	0.852 ± 0.042	-0.729 ± 0.051	3.1
$K^*(1410)^-$	-0.402 ± 0.076	0.050 ± 0.072	0.2
$K^*(1680)^-$	-1.00 ± 0.29	1.69 ± 0.28	1.4
$K^*(892)^+$	0.133 ± 0.008	-0.132 ± 0.007	0.7
$K_0^*(1430)^+$	0.375 ± 0.060	-0.143 ± 0.066	0.2
$K_2^*(1430)^+$	0.088 ± 0.037	-0.057 ± 0.038	0.0
$\rho(770)$	1 (fixed)	0 (fixed)	22.3
$\omega(782)$	-0.0182 ± 0.0019	0.0367 ± 0.0014	0.6
$f_2(1270)$	0.787 ± 0.039	-0.397 ± 0.049	2.7
$\rho(1450)$	0.405 ± 0.079	-0.458 ± 0.116	0.3
β_1	-3.78 ± 0.13	1.23 ± 0.16	–
β_2	9.55 ± 0.20	3.43 ± 0.40	–
β_4	12.97 ± 0.67	1.27 ± 0.66	–
f_{11}^{prod}	-10.22 ± 0.32	-6.35 ± 0.39	–
sum of $\pi^+\pi^-$ S-wave			16.2

Sum of fractions: 1.16

$\sin(2\beta+\gamma)$ with neutral B decays



Interference



$$A \propto V_{cb}V_{ud}^*$$

$$A \propto V_{ub}V_{cd}^* e^{i\delta} \propto \underbrace{A r^{(*)} e^{i\delta} e^{-i\gamma}}$$

strong phase diff.

weak phase diff.

Time-dependent decay rate distribution:

$$P(B^0 \to D^{(*)\mp}\pi^{\pm}, \Delta t) \propto 1 \pm C^{(*)} \cos\left(\Delta m_d \Delta t\right) + S^{(*)\mp} \sin\left(\Delta m_d \Delta t\right)$$

$$P(\overline{B}^0 \to D^{(*)\mp}\pi^{\pm}, \Delta t) \propto 1 \mp C^{(*)} \cos\left(\Delta m_d \Delta t\right) - S^{(*)\pm} \sin\left(\Delta m_d \Delta t\right)$$

$$r^{(*)} = \frac{|A_{DCS}|}{|A_{CF}|} \sim 2\% \qquad C^{(*)} = \frac{1-r^{(*)2}}{1+r^{(*)2}} \approx 1 \qquad S^{(*)\pm} = \frac{2r^{(*)2}}{1+r^{(*)2}} \sin\left(2\beta+\gamma\pm\delta^{(*)}\right)$$

- Large BF for favored decays ($\sim 10^{-3}$)
- Small BF for suppressed decays

⇨ Small *CP* asymmetries

⇨ $r^{(*)}$ cannot be measured with current stat.

⇨ Measurements of **S+** and **S-** determine ($2\beta+\gamma$) and δ if r is an external input

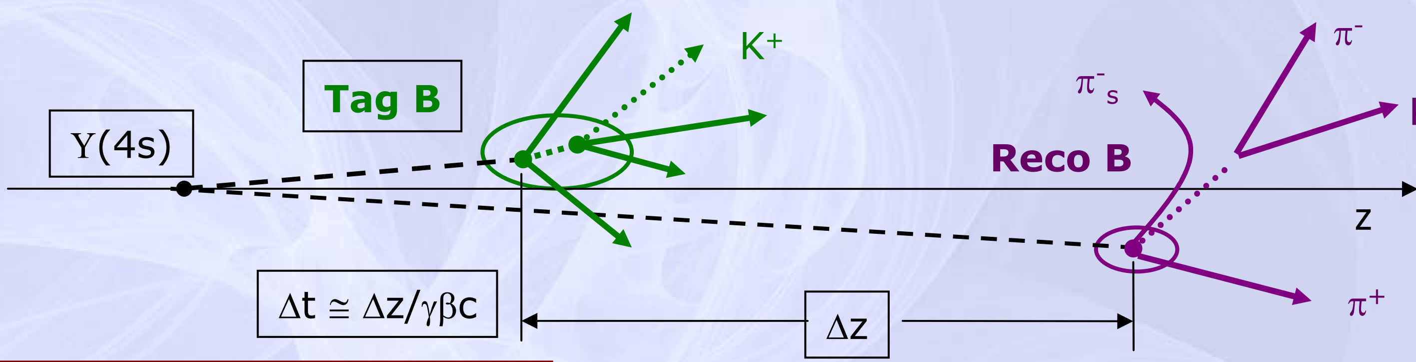
Measuring γ

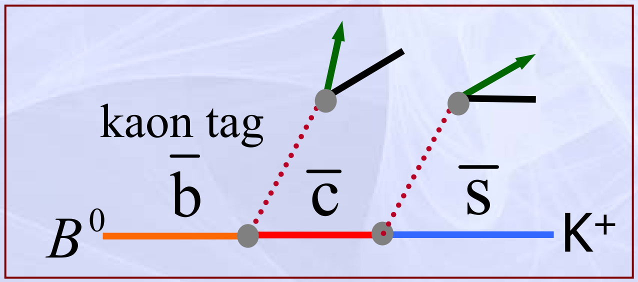
1. Principle
2. GLW
3. ADS
4. GGSZ

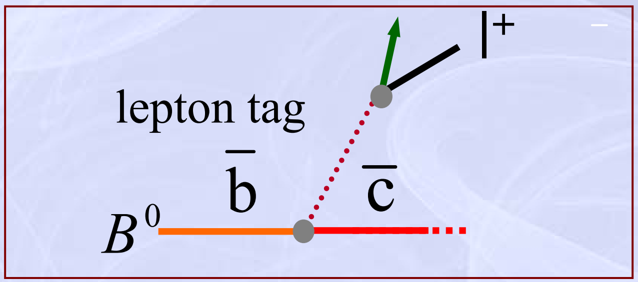
Conclusion

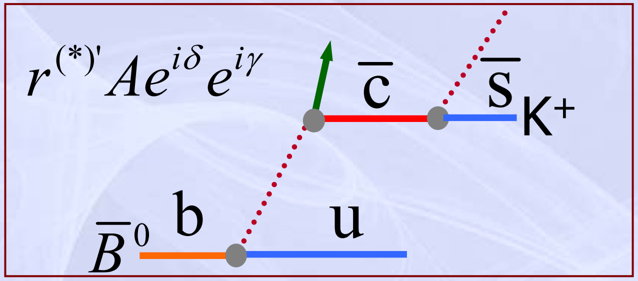
Back-up

sin(2β+γ) with neutral B decays









Kaon tag: Potential competing *CP* violating effects in B_{tag} decays (additional r'and δ'). hep-ex/0504035

Comparable to signal → Modified time distributions

⇨ *Alternative parameterization:*

$$S^{(*)\pm} = \left(a^{(*)} \pm c^{(*)}\right) + b$$

$$a^{(*)} = 2r^{(*)}\sin(2\beta+\gamma)\cos\left(\delta^{(*)}\right)$$

$$\boxed{b = 2r'\sin(2\beta+\gamma)\cos\left(\delta^{(*)}\right)}$$

$$c^{(*)} = 2\cos(2\beta+\gamma)\left(r^{(*)}\sin\delta^{(*)} - \boxed{r'\sin\delta'}\right)$$

0 for lepton tag

Measuring γ

1. Principle
2. GLW
3. ADS
4. GGSZ

Conclusion

Back-up

$B \to D^{(*)\mp} h^{\pm},\ h^{\pm} = \rho^{\pm}, \pi^{\pm}$

Measuring γ

1. Principle
2. GLW
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4. GGSZ

Conclusion

Back-up

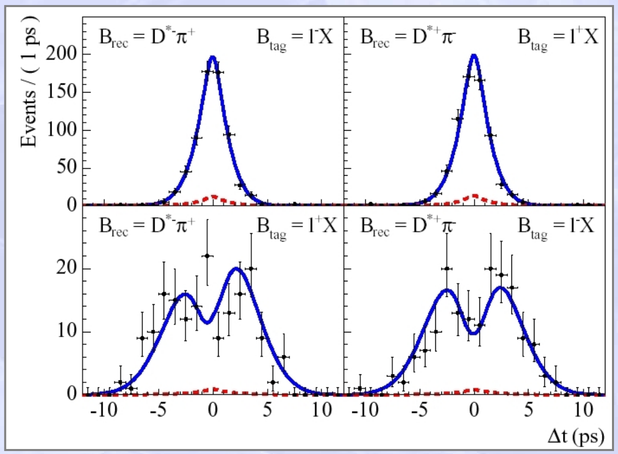
Full reconstruction

$232\times10^6\ B\bar{B}$

Phys.Rev.D73:111101,2006

$D\rho$, $D\pi$, $D^*\pi$

- Excellent purity (80-90%)
- Limited tagging efficiency
- Limited event yields



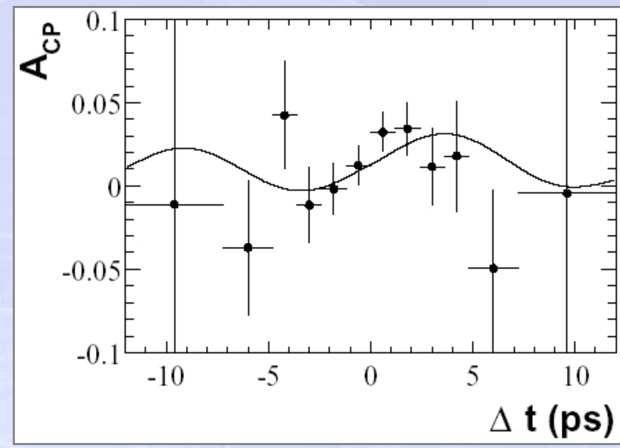
Partial reconstruction

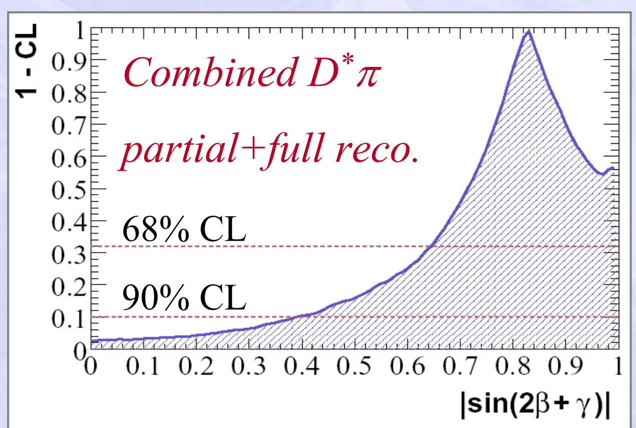
$232\times10^6\ B\bar{B}$

Phys.Rev.D71:112003,2005

$D^*\pi$ *only*

- Only prompt π and soft π from D^*
- Lower purity (30-55%)
- Higher stat (5-6 times fully reco.)



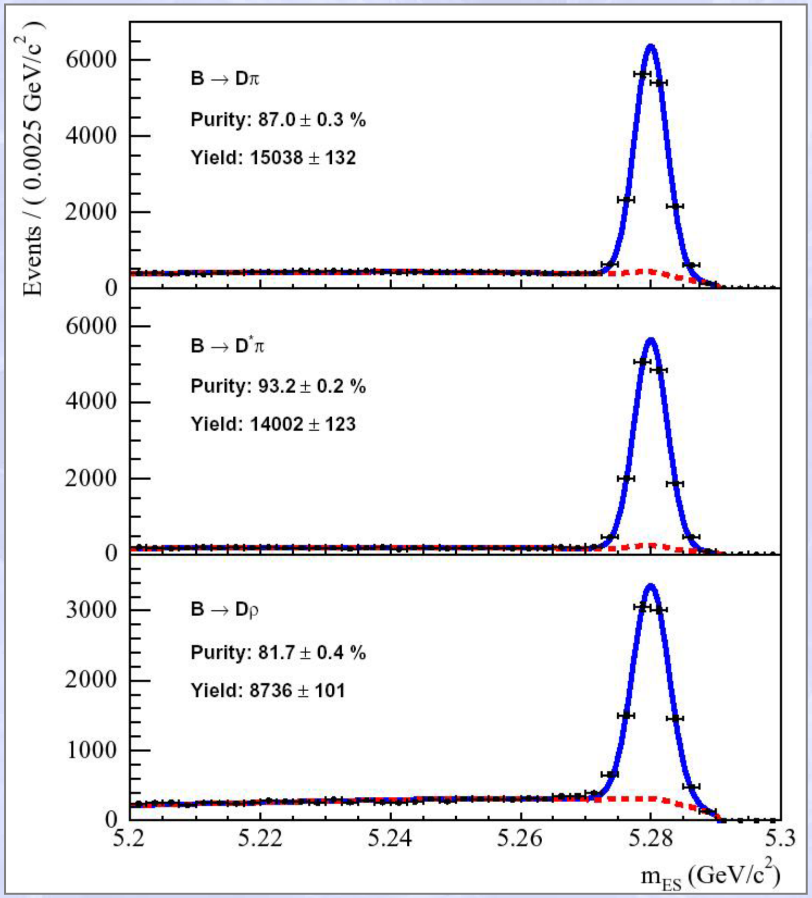


|sin(2β+γ)|>0.64 (68%CL)

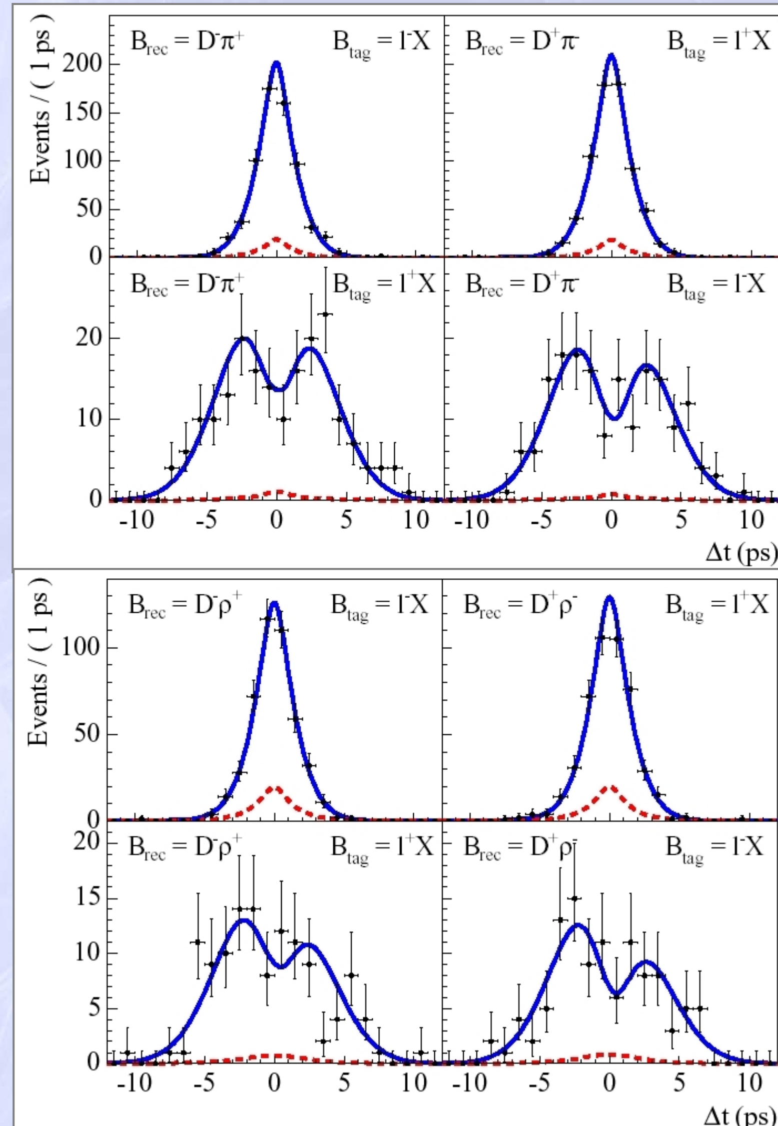
>0.40 (90%CL)

$sin(2\beta+\gamma)$

Purity obtained with full reconstuction



Fitted Δt distributions



$sin(2\beta+\gamma)$

Measuring γ

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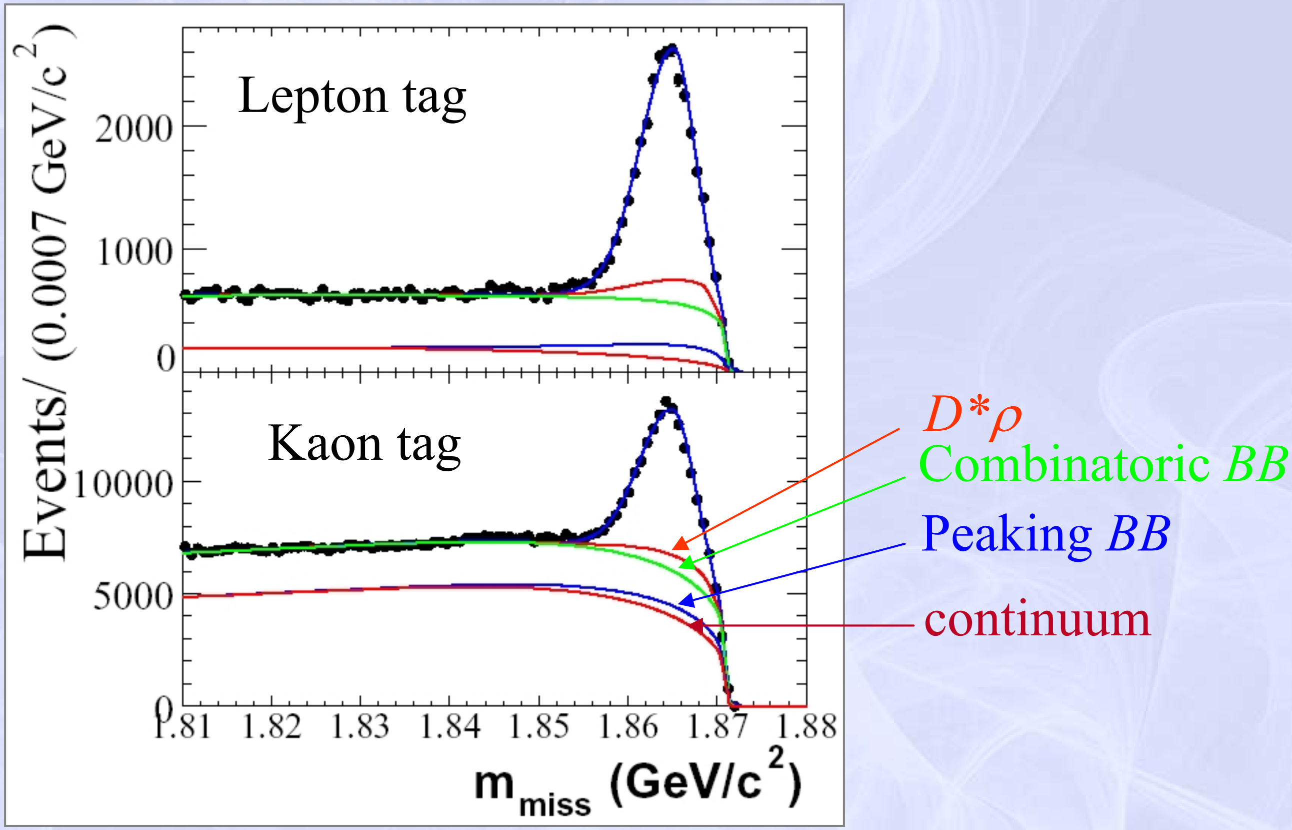
3. ADS
4. GGSZ

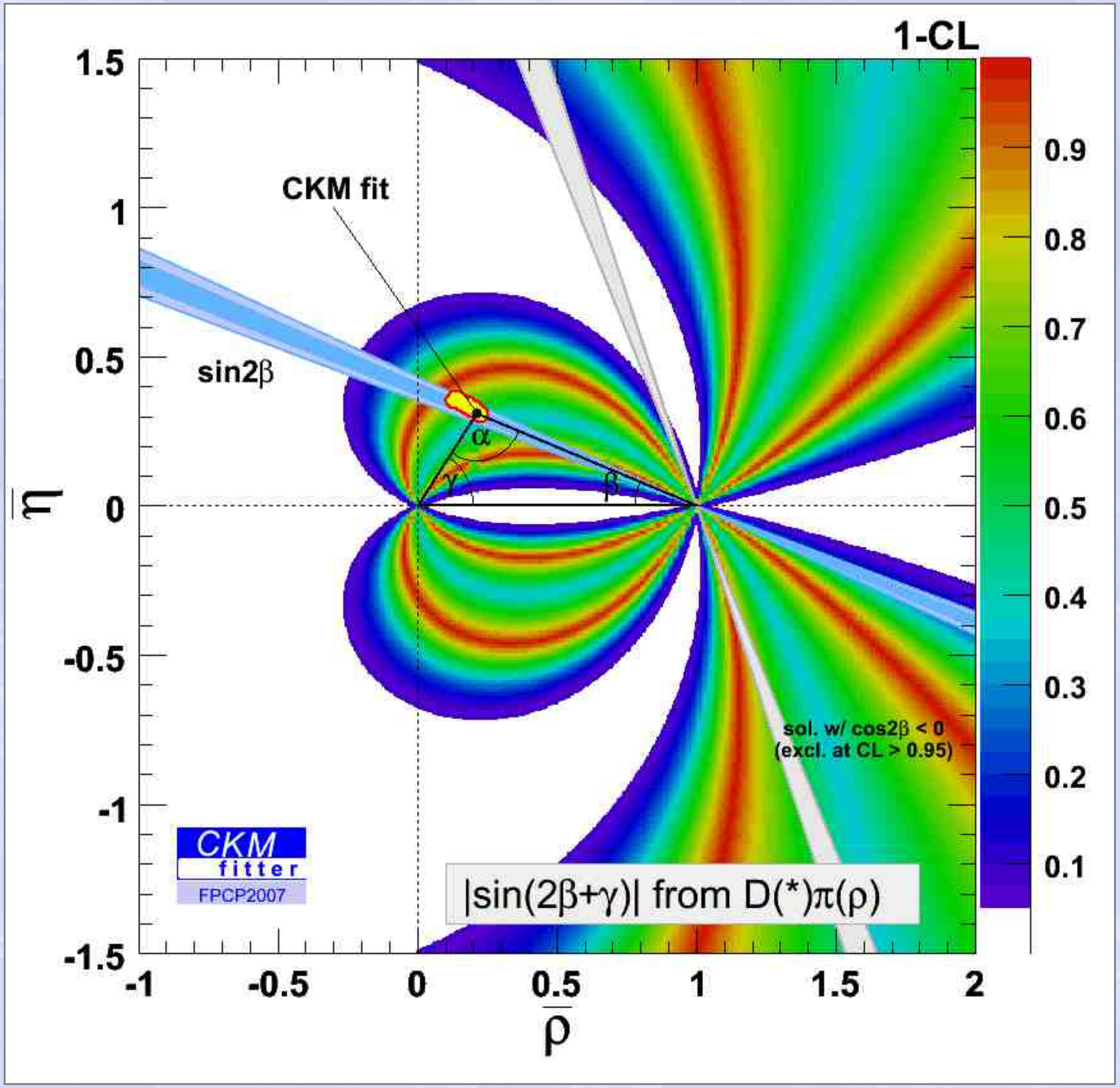
Conclusion

Back-up

Partial $B \to D^{*}\pi^{\pm}$ reco.



$sin(2\beta+\gamma)$



Measuring γ

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