γ measurement in B→D(*)K(*) decays with a D^0 Dalitz analysis

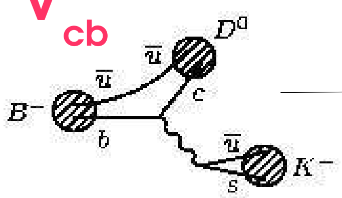
Nicola Neri

Universita' di Pisa & INFN

Dalitz workshop
SLAC, 5 Dec 2004

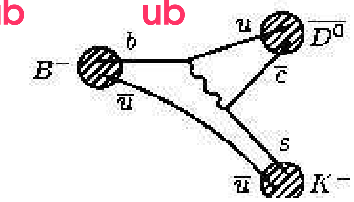
Method of Measurement

V_{cb}



Same final state
$B^- \to D(^*)K^-$
Interference

$V_{ub} = |V_{ub}| e^{-i\gamma}$



$A(B^- \to D^0 K^-) = A_B$

$A(B^- \to \overline{D}^0 K^-) = A_b r_B e^{+i(\delta_B - \gamma)}$

$A(B^+ \to \overline{D}^0 K^+) = A_b r_B e^{+i(\delta_B + \gamma)}$

$r_B = |A(B^- \to \overline{D}^0 K^-) / A(B^- \to D^0 K^-)|$

$A(D^0 \to K_S \pi^- \pi^+) = A(s_{12}, s_{13})$

$A(D^0 \to K_S \pi^+ \pi^-) = A(s_{13}, s_{12})$

$A(\overline{D}^0 \to K_S \pi^+ \pi^-) = A(D^0 \to K_S \pi^- \pi^+)$

$s_{12} = m^2(K_S \pi^-)$ $\quad$ $s_{13} = m^2(K_S \pi^+)$

$$d\hat{\Gamma}(B^- \to (K_S \pi^- \pi^+)_D K^-) = \Big(A_{12,13}^2 + r_B^2 A_{13,12}^2 + 2 r_B \, Re\Big[A_D(s_{12}, s_{13}) A_D^*(s_{13}, s_{12}) \, e^{-i(\delta_B - \gamma)}\Big]\Big) dp$$

($\gamma \in \gamma + \pi$; $\delta \in \delta + \pi$) ambiguity is intrinsic in the amplitude.

Basics of the strategy for γ extraction

$$B+: \quad pdf_{+} = | \, f(s_{12},s_{13}) + r_b \, e^{i(\gamma+\delta)} f(s_{13},s_{12}) \, |^2$$

$$B-: \quad pdf_{-} = | \, f(s_{13},s_{12}) + r_b \, e^{i(-\gamma+\delta)} f(s_{12},s_{13}) \, |^2$$

Gamma change sign in the two different B charge samples.

V_{cb} amplitude

V_{ub} amplitude

The Dalitz model gives $f(s_{12},s_{13})$.

The CP Dalitz fit extracts r_B, γ, δ.

Dalitz peculiarities

This method exploits the interference between the V_{ub} and V_{cb} diagrams, as the GWL, ADS methods.

Advantages:

- Interference is proportional to r_B~0.1 and to $A(s_{12},s_{13})|A^*(s_{13},s_{12})$ which is large in several regions of the Dalitz plot, i.e.

K*(892) DCS, ρ(770), K^{*0}(1430) DCS.

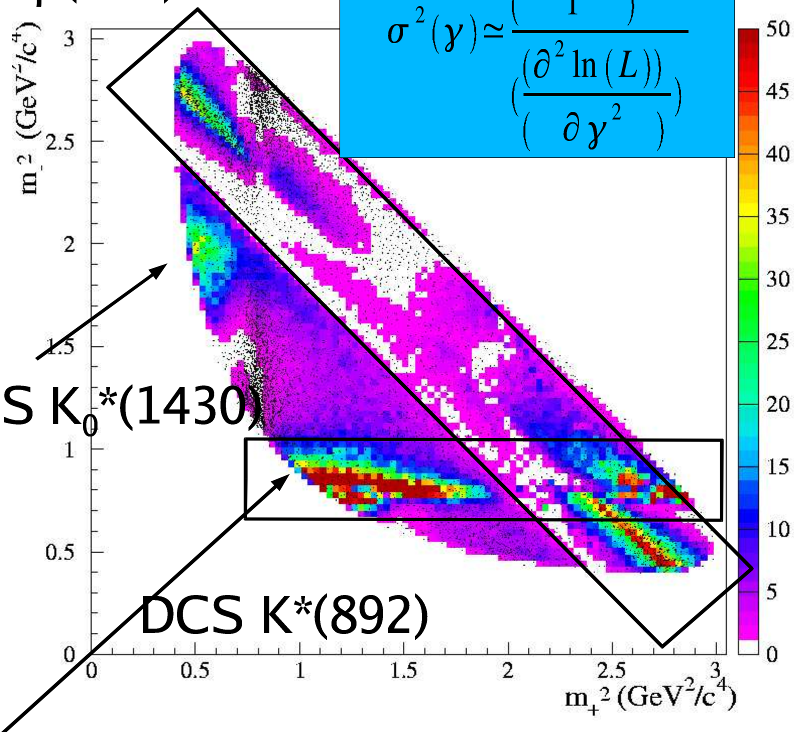
- Need to reconstruct only one decay channel which has relatively high statistics.

Disadvantages:

- Dalitz plot analysis need to assume a model dependency which limits asymptotically the sensitivity of the method, with the systematic error.
- Model independent approach exists but not convenient with the present statistics.

HEP-PH/0303187 A.Giri,Y.Grossman,A.Soffer,J.Zupan

Sensitivity to γ



$$\sigma^2(\gamma) \simeq \frac{(\quad 1 \quad)}{\left(\frac{(\partial^2 \ln(L))}{(\quad \partial \gamma^2 \quad)}\right)}$$

Not all the events in the Dalitz are sensitive to γ.
We need regions where interference term is large,
let's consider the K*(892) regions:

Maximal interference:

B decay	•	D decay	interfere	B decay	•	D decay
Vub	•	A_D(CA)	⇔	Vcb	•	A_D(DCS)
small	•	large	⇔	large	•	small

$r_B A_D(s_{12},s_{13})$ = from Vub $A_D(s_{12},s_{13})$ CA region D^0 Decay
$A^*_D(s_{13},s_{12})$ = from Vcb $A^*_D(s_{13},s_{12})$ DCS region D^0 Decay

Most sensitive regions large values of likelihood 2nd derivative, i.e. Small error γ.

$$d\hat{\Gamma}(B^- \to (K_S\pi^-\pi^+)_D K^-) = \Big(A^2_{12,13} + r_B^2 A^2_{13,12}$$
$$+ 2r_B\, Re\Big[A_D(s_{12},s_{13})\, A^*_D(s_{13},s_{12})\, e^{-i(\delta_B-\gamma)}\Big]\Big)dp$$

Interference term

How do we deal with the model uncertainty

The measurement is still dominated by the statistical error.
The main systematic error is due to the model uncertainty, it becomes more important while the statistics increases.

Model uncertainty:

- Changing the Blatt-Weisskopf penetration factors *negligible*
- Taking into account the fit uncertainty of the phases and amplitudes of the resonances. *sizeble*
- Using different models for the Ks$\pi\pi$ Dalitz decay: *dominant*
    - (CLEO model 10 resonances instead of 16)
    - Removing not estabilished scalar resonances: σ_1, σ_2

Some suggestions for model error evaluation?

Future plans: new D^0 decay modes for γ extraction

Large sensitivity to γ decay modes:

- D^0 decays with DCS and CA overlapping regions and CP eigenstates are requested.
- The more interference regions in the Dalitz plot the better is the sensitivity to γ.

3-body decays

Decay mode	BR	comment	status	γ sensitivity
$\bar{K}^0\pi^+\pi^-$	***5.97±0.35%***	***"golden mode"***	***done***	***good***
$\bar{K}^0 K^+K^-$	1.03±0.10%	clean signal, low BR	done	poor
$\pi^+\pi^-\pi^0$	1.1±0.4%	high bkg	working	poor
$K^0 K^- \pi^+$	$(6.9\pm1.0)\cdot10^{-3}$	low BR	working	poor
$\bar{K}^0 K^+\pi^-$	$(5.3\pm1.0)\cdot10^{-3}$	low BR	working	poor
$K^+K^-\pi^0$	$(1.24\pm0.35)\cdot10^{-3}$	low BR	working	poor
$K^-\pi^+\pi^0$	***13.0±0.8% CA***	***2 dalitz plot***	***just started***	***?***
$K^+\pi^-\pi^0$	***$(5.6\pm1.7)\cdot10^{-4}$ DCS***			

The most promising D^0 decay modes have been investigated. Low BR and/or high bkg level afflicts most of the D^0 3-body decays.
Under study the $D^0\text{->}K^-\pi^+\pi^0$ decay mode which requires the DCS $D^0\text{->}K^+\pi^-\pi^0$ dalitz plot analysis.

What about 4-body decays?

Decay mode	BR	comment	status	γ sensitivity
$K^-\pi^+\pi^+\pi^-$	7.46±0.31%	challenging	still to investigate	?
$\bar{K}^0\pi^+\pi^-\pi^0$	*10.9±1.3%*	*challenging*	*still to investigate*	*?*

4-body decays are more complicated and difficult decays to reconstruct. Higher bkg is expected due to large multiplicity tracks events. The $Ks\pi^+\pi^-\pi^0$ decay mode has a high branching ratio and seems interesting to study. An evaluation of the bkg is needed in order to quote the interest for the γ measurement.

Is it feasible to study a 4-body “dalitz plot“?
Or one should not even think about it?

Conclusions

- Dalitz plot is a very powerful tool for the γ measurement.
- Studies undergoing for a more refined dalitz model. Present statistical error is large compared to the model uncertainty.
- 3-body decays are under study in the Breco AWG, to evaluate the sensitivity to γ with current or future statistics.
- 4-body decay $K_s\pi^+\pi^-\pi^0$ seems interesting because of the high branching ratio. Is it possible to perform a 4-body dalitz analysis?
- **A joint effort with the Charm AWG would be much appreciated and hope very fruitful.**

Backup

Slides

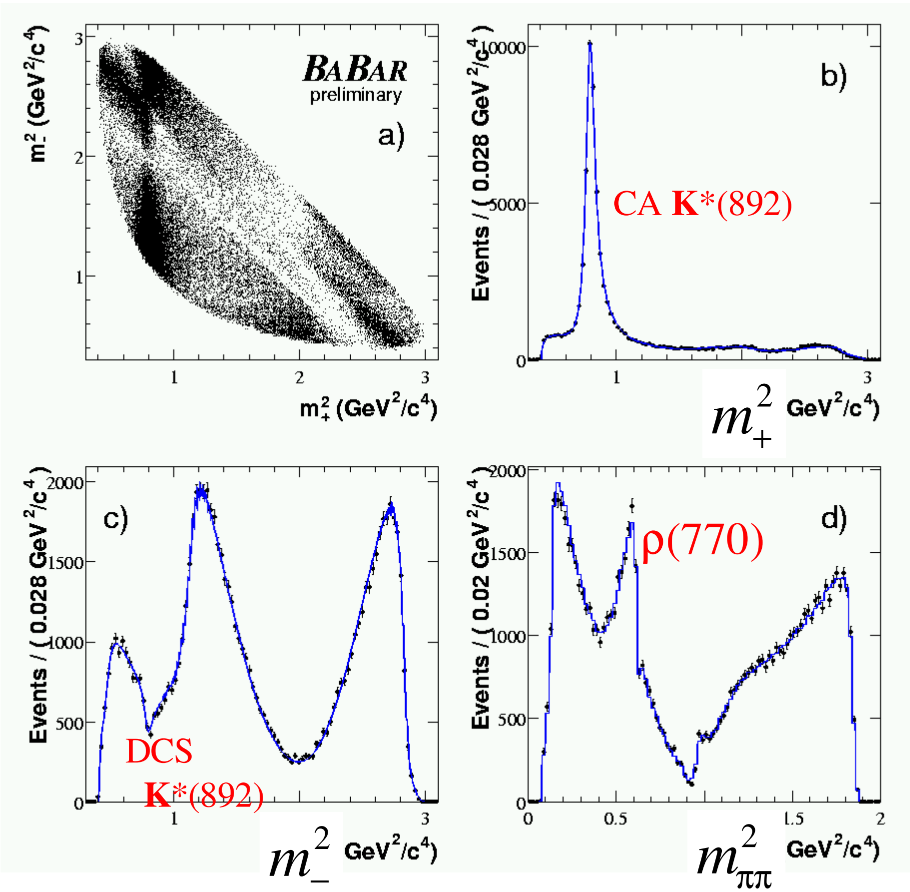
The BaBar Model

BaBar model 16 resonances + 1 Non Resonant term.
Removed DCS K*(1680), and added K*(1410), ρ(1450) respect to Belle Model.

Resonance	Amplitude	phase (degrees)	fit fraction (%)
$K^*(892)$	1.781 ± 0.018	131.0 ± 0.79	58.60
$\rho^0(770)$	1 (fixed)	0(fixed)	22.36
$K^*(892)$ DCS	0.1796 ± 0.0079	-44.1 ± 2.4	0.60
$\omega(782)$	0.0391 ± 0.0016	115.3 ± 2.5	0.56
$f_0(980)$	0.4817 ± 0.011	218.2 ± 2.2	6.09
$f_0(1370)$	2.25 ± 0.28	113.2 ± 4.4	3.20
$f_2(1270)$	0.922 ± 0.040	-21.3 ± 2.8	3.00
$K_0^*(1430)$	2.447 ± 0.073	-8.3 ± 2.0	8.32
$K_0^*(1430)$ DCS	0.368 ± 0.067	-342.2 ± 9.8	0.19
$K_2^*(1430)$	1.054 ± 0.045	-54.3 ± 2.5	2.74
$K_2^*(1430)$ DCS	0.075 ± 0.036	-104 ± 30	0.01
→ $K^*(1410)$	0.515 ± 0.071	154 ± 10	0.37
$K^*(1680)$	0.89 ± 0.29	-139 ± 19	0.28
→ $\rho(1450)$	0.515 ± 0.092	38 ± 13	0.24
σ_1	1.358 ± 0.040	-177.9 ± 2.4	9.27
σ_2	0.340 ± 0.024	-207.0 ± 3.8	1.34
Non resonant	3.53 ± 0.44	-232.4 ± 4.7	7.30

Mass and widths are fixed to the PDG 2004 values.
Except for sigma1 sigma2 we fit for those parameters.

$\bar{D}^0(K_S\pi^+\pi^-)$ Dalitz model



Resonance	Amplitude	Phase (degrees)	Fraction (%)
$K^*(892)$	1.777 ± 0.018	131.0 ± 0.81	58.51
$\rho^0(770)$	1 (fixed)	0(fixed)	22.33
$K^*(892)$ DCS	0.1789 ± 0.0080	-44.0 ± 2.4	0.59
$\omega(782)$	0.0391 ± 0.0016	114.8 ± 2.5	0.56
$f_0(980)$	0.469 ± 0.011	213.4 ± 2.2	5.81
$f_0(1370)$	2.32 ± 0.31	114.1 ± 4.4	3.39
$f_2(1270)$	0.915 ± 0.041	-22.0 ± 2.9	2.95
$K_0^*(1430)$	2.454 ± 0.074	-7.9 ± 2.0	8.37
$K_0^*(1430)$ DCS	0.350 ± 0.069	$-344. \pm 10.$	0.60
$K_2^*(1430)$	1.045 ± 0.045	-53.1 ± 2.6	2.70
$K_2^*(1430)$ DCS	0.074 ± 0.038	-98 ± 30	0.01
$K^*(1410)$	0.524 ± 0.073	-157 ± 10	0.39
$K^*(1680)$	0.99 ± 0.31	-144 ± 18	0.35
$\rho(1450)$	0.554 ± 0.097	$35 \pm 12.$	0.28
σ_1	1.346 ± 0.044	-177.5 ± 2.5	9.11
σ_2	0.292 ± 0.025	-206.8 ± 4.3	0.98
Non resonant	3.41 ± 0.48	-233.9 ± 5.0	6.82

No D-mixing, No CP violation in D decays

The CLEO model

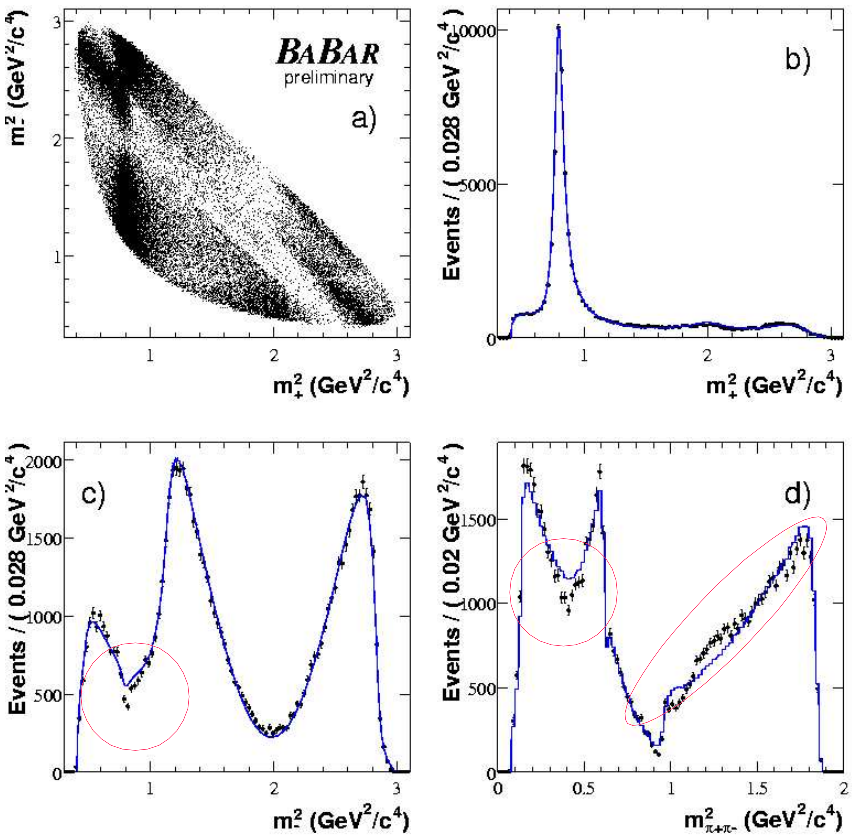
CLEO model 10 resonances + 1 Non Resonant term.

TABLE I. Standard fit results. The errors shown are statistical, experimental systematic, and modeling systematic, respectively. See the text for further discussion.

Component	Amplitude	Phase	Fit fraction (%)
$K^*(892)^+\pi^- \times B[K^*(892)^+ \to K^0\pi^+]$	$(11 \pm 2^{+4+4}_{-1-1}) \times 10^{-2}$	$321 \pm 10 \pm 3^{+15}_{-5}$	$0.34 \pm 0.13^{+0.31+0.26}_{-0.03-0.02}$
$\overline{K^0}\rho^0$	1.0 (fixed)	0 (fixed)	$26.4 \pm 0.9^{+0.9+0.4}_{-0.7-2.5}$
$\overline{K^0}\omega \times B(\omega \to \pi^+\pi^-)$	$(37 \pm 5 \pm 1^{+3}_{-8}) \times 10^{-3}$	$114 \pm 7^{+6+2}_{-4-5}$	$0.72 \pm 0.18^{+0.04+0.10}_{-0.06-0.07}$
$K^*(892)^-\pi^+ \times B[K^*(892)^- \to \overline{K^0}\pi^-]$	$1.56 \pm 0.03 \pm 0.02^{+0.15}_{-0.03}$	$150 \pm 2 \pm 2^{+2}_{-5}$	$65.7 \pm 1.3^{+1.1+1.4}_{-2.6-3.0}$
$\overline{K^0}f_0(980) \times B[f_0(980) \to \pi^+\pi^-]$	$0.34 \pm 0.02^{+0.04+0.04}_{-0.03-0.02}$	$188 \pm 4^{+5+8}_{-3-6}$	$4.3 \pm 0.5^{+1.1}_{-0.4} \pm 0.5$
$\overline{K^0}f_2(1270) \times B[f_2(1270) \to \pi^+\pi^-]$	$0.7 \pm 0.2^{+0.3}_{-0.1} \pm 0.4$	$308 \pm 12^{+15+66}_{-25-6}$	$0.27 \pm 0.15^{+0.24+0.28}_{-0.09-0.14}$
$\overline{K^0}f_0(1370) \times B[f_0(1370) \to \pi^+\pi^-]$	$1.8 \pm 0.1^{+0.2+0.2}_{-0.1-0.6}$	$85 \pm 4^{+4+34}_{-1-13}$	$9.9 \pm 1.1^{+2.4+1.4}_{-1.1-4.3}$
$K_0^*(1430)^-\pi^+ \times B[K_0^*(1430)^- \to \overline{K^0}\pi^-]$	$2.0 \pm 0.1^{+0.1+0.5}_{-0.2-0.1}$	$3 \pm 4 \pm 4^{+7}_{-15}$	$7.3 \pm 0.7^{+0.4+3.1}_{-0.9-0.7}$
$K_2^*(1430)^-\pi^+ \times B[K_2^*(1430)^- \to \overline{K^0}\pi^-]$	$1.0 \pm 0.1 \pm 0.1^{+0.3}_{-0.1}$	$155 \pm 7^{+1+7}_{-4-24}$	$1.1 \pm 0.2^{+0.3+0.6}_{-0.1-0.3}$
$K^*(1680)^-\pi^+ \times B[K^*(1680)^- \to \overline{K^0}\pi^-]$	$5.6 \pm 0.6^{+0.7}_{-0.4} \pm 4.0$	$174 \pm 6^{+10+13}_{-3\;-19}$	$2.2 \pm 0.4^{+0.5+1.7}_{-0.3-1.5}$
$\overline{K^0}\pi^+\pi^-$ nonresonant	$1.1 \pm 0.3^{+0.5+0.9}_{-0.2-0.7}$	$160 \pm 11^{+30+55}_{-18-52}$	$0.9 \pm 0.4^{+1.0+1.7}_{-0.3-0.2}$

The CLEO model

With >10x more data than CLEO, we find that the model with 10 resonances is insufficient to describe the data.



BaBar Data with CLEO model fit overimposed.