B- → $D^0(K_s \pi+ \pi-)K-$ dalitz fit

Measurement of CKM angle γ via dalitz technique

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On behalf of BaBar Collaboration

Outline:

1. Description of the method
2. Events selection
3. Background fighting
4. The D^0 dalitz model
5. Statistics and Systematic error.

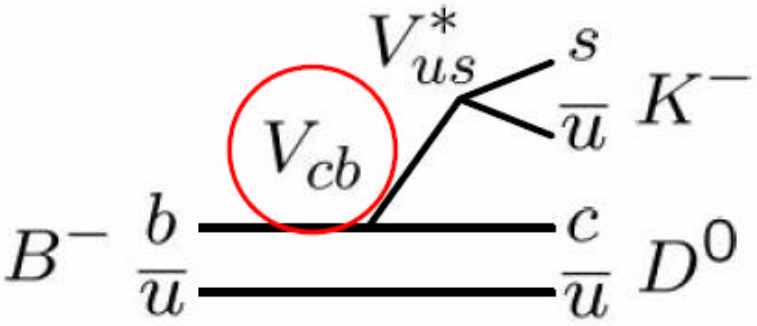
DPF 2004, UC Riverside, August 26-31, 2004

BABAR

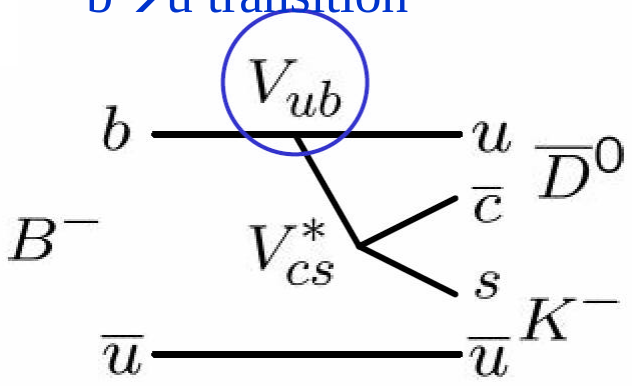
Probe CKM γ via B- → D^0K- channel

b→c transition

$e^{id_B}e^{-ig}$



b→u transition



Interference occur when D^0 and $\overline{D}^0$ decay to same final state

Relative size (r_B) of B decay amplitudes

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

Not well constrained by theory.

Larger r_B, larger interference, **better** γ experimental precision

Work was pioneered by Belle hep-ex/0406067 $r_B = 0.26^{+0.10}_{-0.14} \pm 0.03 \pm 0.04$

$m^2_+ : M(K_s \pi+)^2$
$m^2_- : M(K_s \pi-)^2$

Looking interference on dalitz plot

$$B+: \quad pdf = | f(m^2_+,m^2_-)+r_b\, e^{i(\gamma+\delta)}\, f(m^2_-,m^2_+) |^2$$

$$B-: \quad pdf = | f(m^2_-,m^2_+)+r_b\, e^{i(-\gamma+\delta)}\, f(m^2_+,m^2_-) |^2$$

Weak phase change sign
Strong phase does not.

D^0 dalitz amplitude

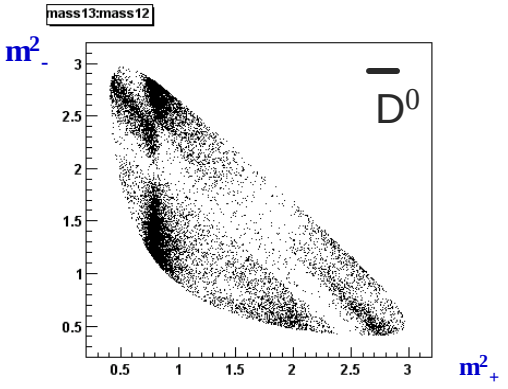
Fit B+ → give r_b and $\theta_+=\gamma+\delta$

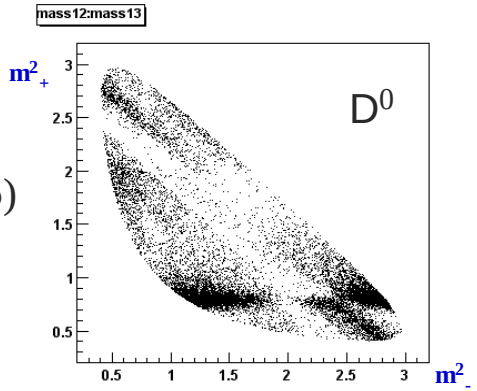
Fit B- → give r_b and $\theta_-=-\gamma+\delta$

We have → $\gamma=(\theta_+ - \theta_-)/2$

Pictorially:

$$B+: = \left| \overline{D^0} + r_b e^{i(\gamma+\delta)} D^0 \right|^2$$





Events Selection

B-→D(*)^0 K-, D^0→K$_s$ π+ π-

Candidate selections

- K$_s$→π+π- : |m(K$_s$)-PDG| < 9MeV
- D^0→K$_s$ π+ π- : |m(D^0)-PDG| < 12MeV
- Bachlor Kaon: separate Kaons and Pions from DIRC

D*^{0} Candidate selections

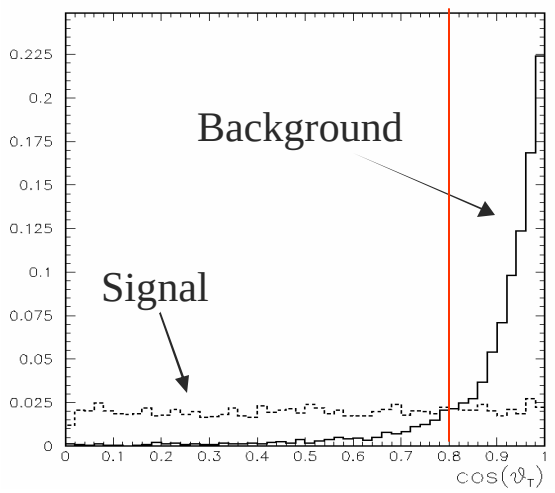
- Select γ, π^0 from the Electromagnetic Calorimeter
- |Δm-Δm(PDG)|<2.5 MeV in D^{0}π^0 and <10 MeV in the D^{0}γ mode

Δm:mass difference between D*-D^0

Background suppression:

- |Cos(θ$_T$)|<0.8 suppress jet-like qq background
- |ΔE|<30MeV suppress the BB-component
- Legendre Fisher to further suppressed qq background.
- Cos(α_Ks) < 0.99 suppressed fake K$_s$

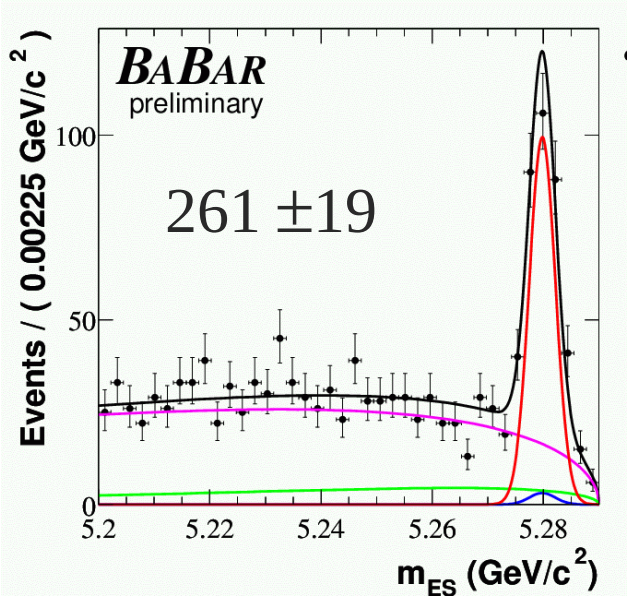
α_Ks : angle between Ks flight length and its momentum vector



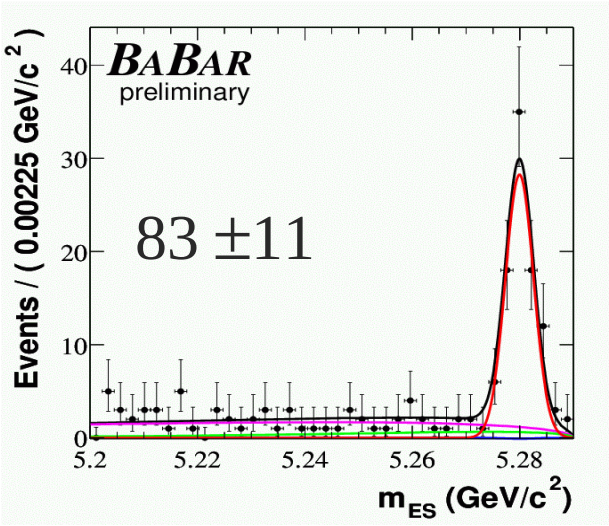
211 Millions $B\bar{B}$ pairs

Events selections

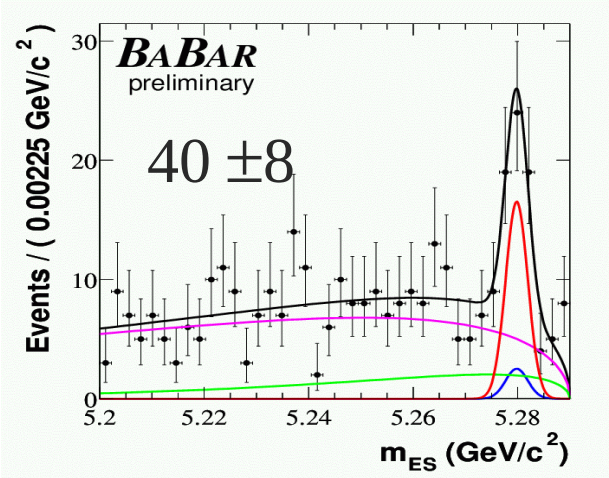
D^0K



$D^{*0}(D^0\pi^0)K$



$D^{*0}(D^0\gamma)K$



Legend:

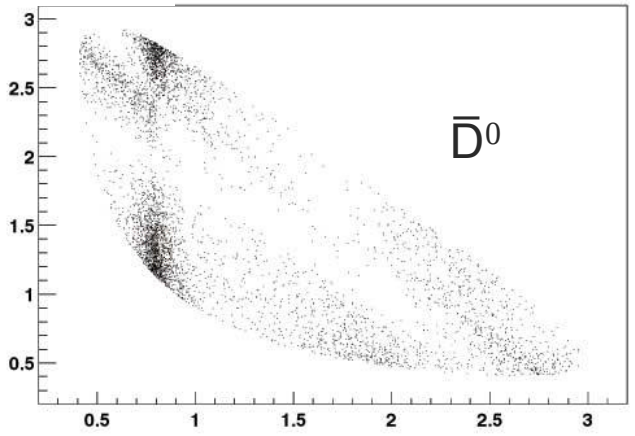
Black: Total pdf
Red: Signal events
Pink: udsc background events
Green: BB background events
Blue: Dπ background events

Source of Background I

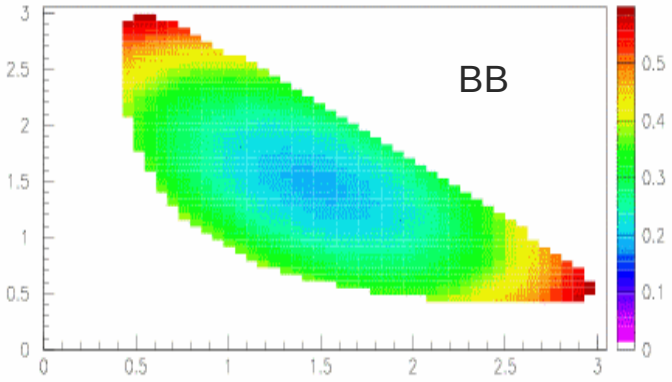
In the dalitz plot analysis, one need:

a.) The fraction of the background
b.) The dalitz plot shapes

- $B \rightarrow D^0\pi$ (~6%)
  - Shapes: From D dalitz model

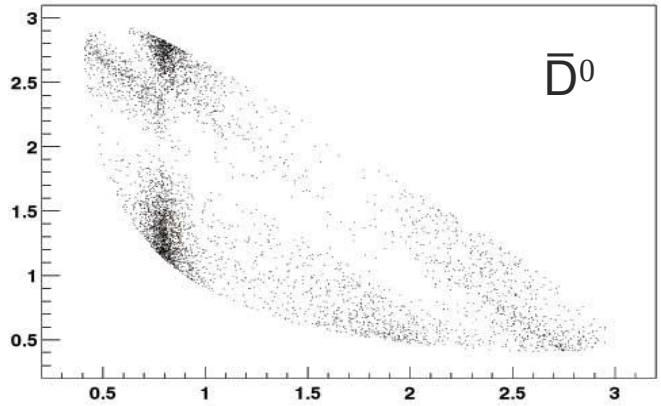


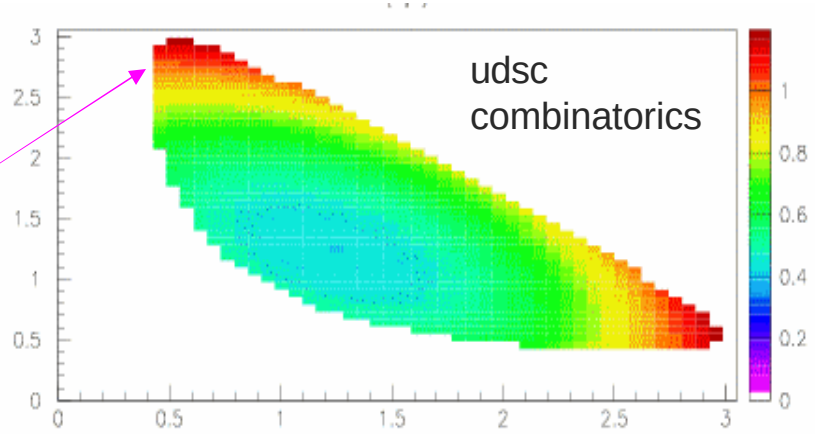
- Generic B^+/B^0 background(~5%)
  - Shapes: From Generic BB Monte Carlo



Source of background II

- udsc background(~26%)
  - In this background there are 21% are real $D^0 \rightarrow K_s \pi^+ \pi^-$ candidate, so need to separate:
    - Real D^0 candidiate(21%): D^0 dalitz model
    - Fake D^0candidate(Combinatorics)(79%): Shapes: from Off-resonance sample





Notice in the combinatorics the dalitz distribution is not flat, it was due to the soft π and the events are more often pile up at the corner of the dalitz plot.

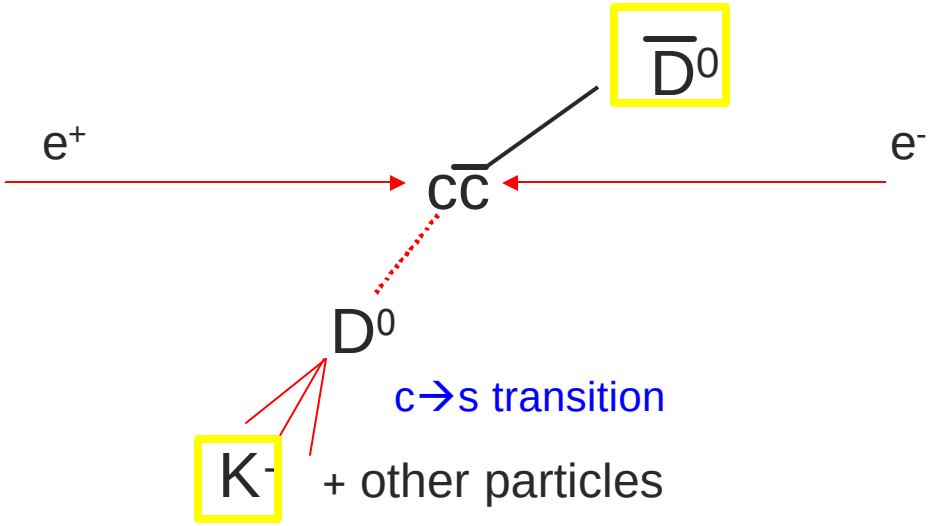
Understand background III:

Suppose want to select $B^- \rightarrow D^0 K^-$

V_{ub} like contribution

More often in cc bkg, we select as $B^- \rightarrow \bar{D}^0 K^-$

Flavor tagging not correct



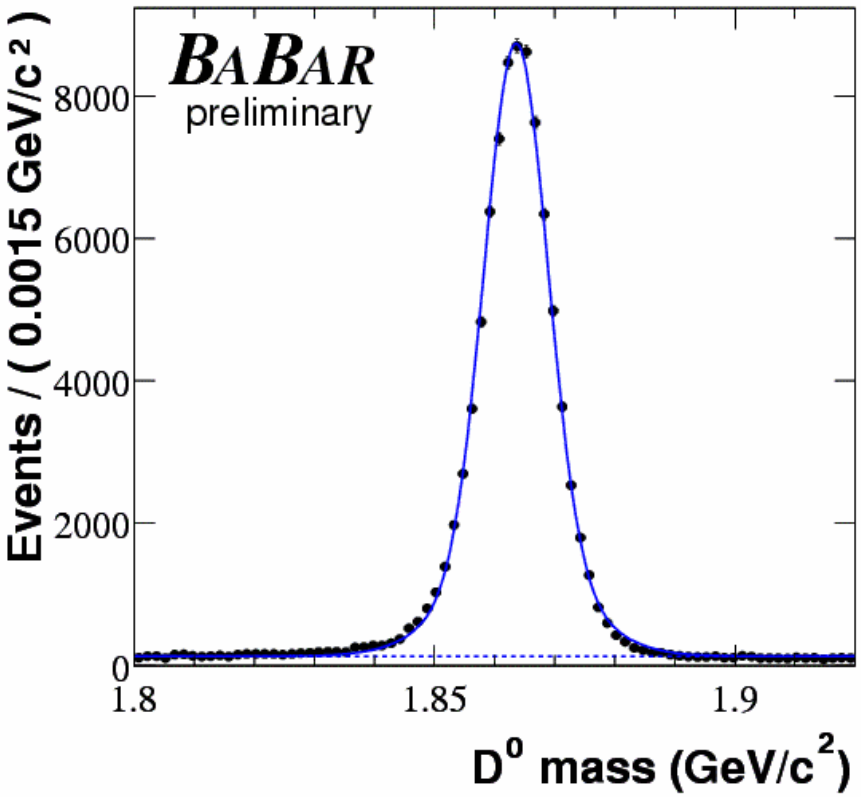
The wrong tagging rate is 79.2%
(estimated from MC)

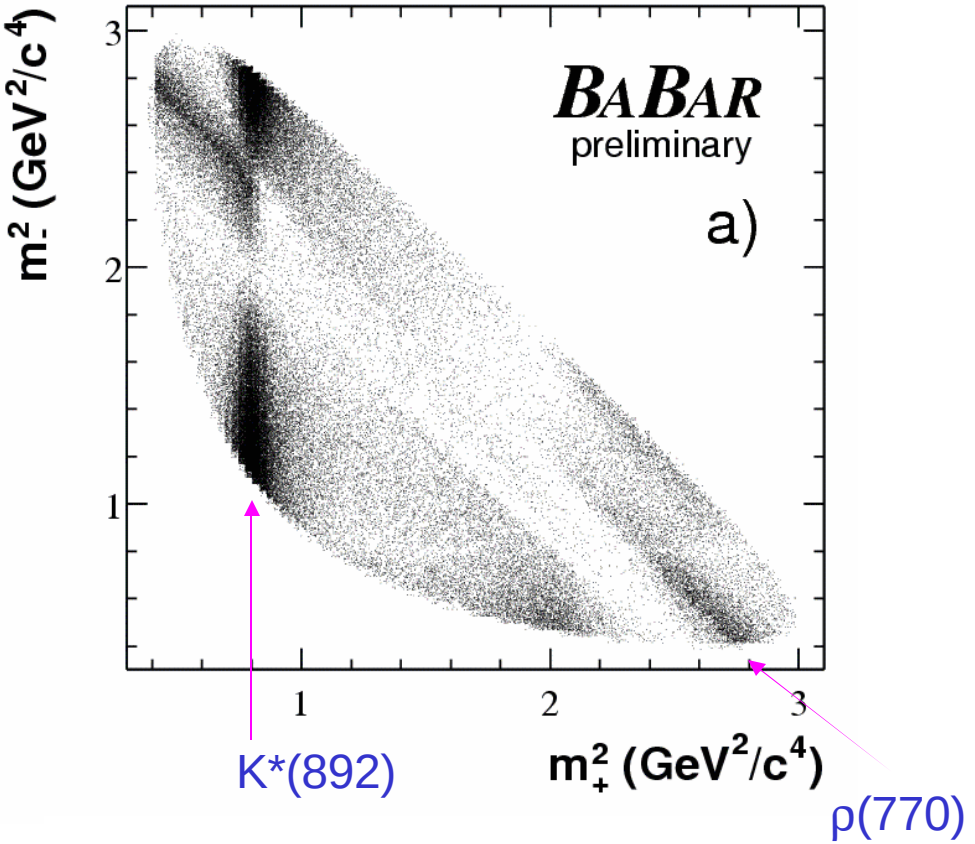
If one neglect this charge correlation effect, the r_b is biased.

From the toy MC study, neglecting this effect leads to a +0.02 bias on r_b

Determined on D ® $D^0 p$ sample*

The D^0 dalitz plot





Purity is 97%

81496 events selected using 91.5 fb^{-1} data using $D^* \rightarrow D^0 \pi$ sample

The dalitz (Isobar) model

- We assumed the D^0 amplitude is represented by a sum of 2-body decay amplitude + non-resonant component (Isobar model)

Mathematically:

$$\sum_j a_j e^{iq_j} \times^J \mathrm{M}_r \times BW^r + a_0 e^{iq_0}$$

--Angular Dependence (spin 0,1,2)

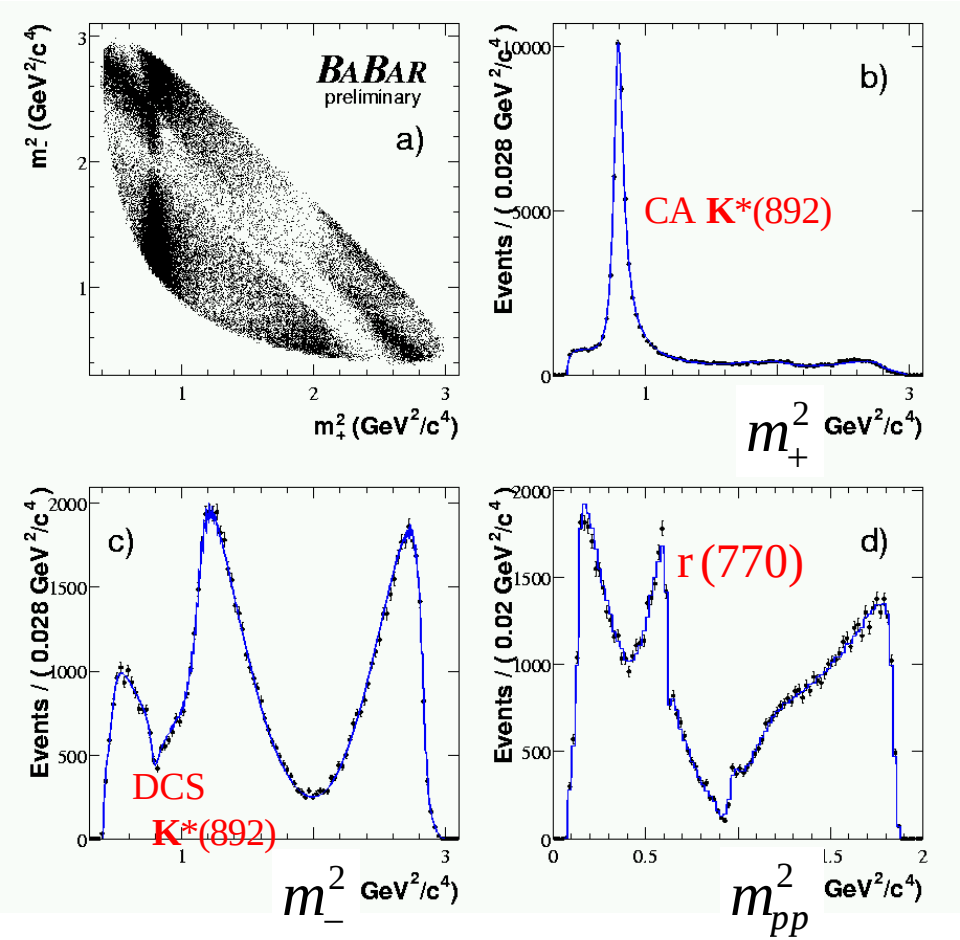
--Relativistic Breit-Wigner Form Factor (the resonance!)[1]

Non-resonance term

1. For ρ(770) and ρ(1450) we adopt Gounaris-Sakurai parameterization, see the mini-review on PDG

Determined on D* ® D^0p sample

The dalitz model fit

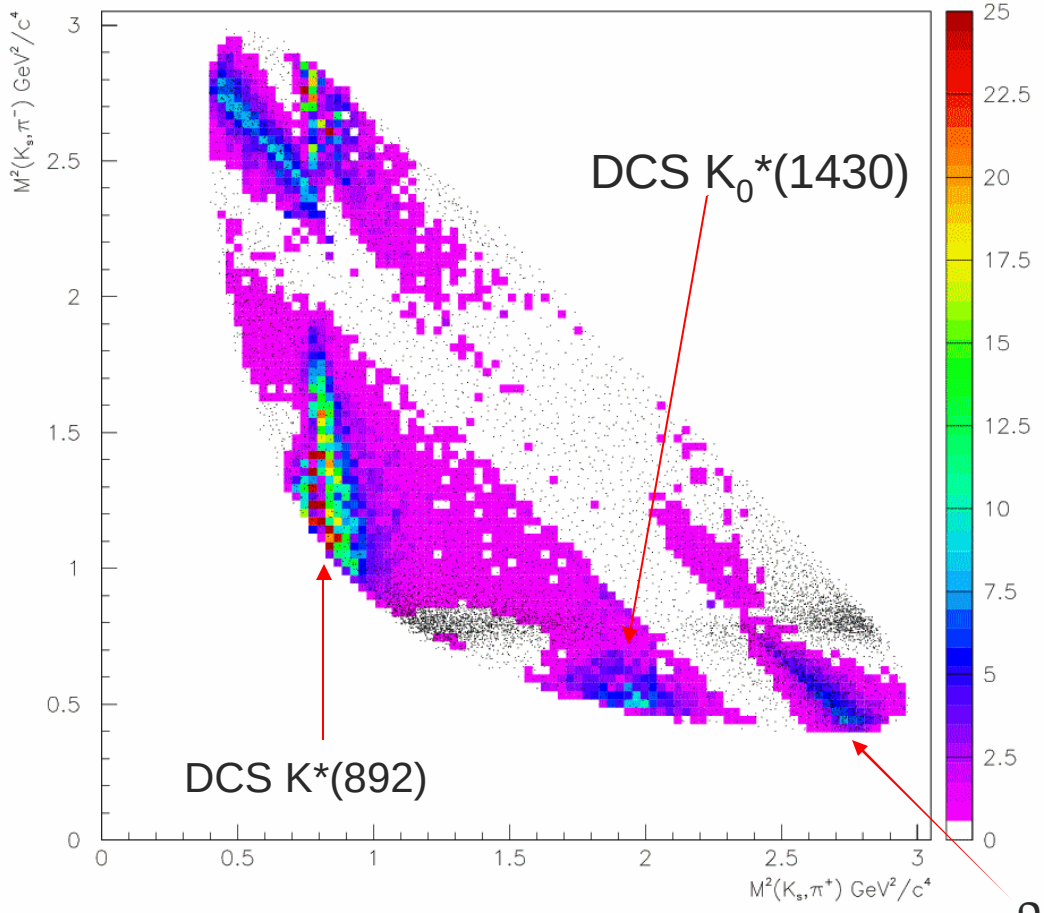


Resonance	Amplitude	Phase (degrees)	Fraction (%)
$K^*(892)$	1.777 ± 0.018	131.0 ± 0.81	58.51
$\rho^0(770)$	1 (fixed)	0(fixed)	22.33
$K^*(892)$ DCS	0.1789 ± 0.0080	-44.0 ± 2.4	0.59
$\omega(782)$	0.0391 ± 0.0016	114.8 ± 2.5	0.56
$f_0(980)$	0.469 ± 0.011	213.4 ± 2.2	5.81
$f_0(1370)$	2.32 ± 0.31	114.1 ± 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

Total fit-Fraction is 124%

13 resonances + 3 DCS partner + 1 non resonant component

Which part of the dalitz plot is sensitive to γ?



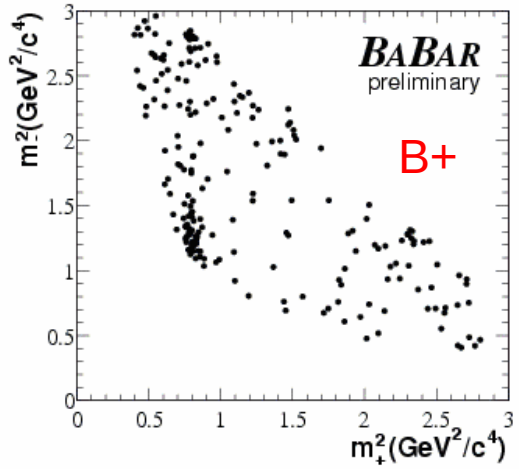
We computed the 2nd derivative of the likelihood w.r.t to γ to see which region is most sensitive (hot region).

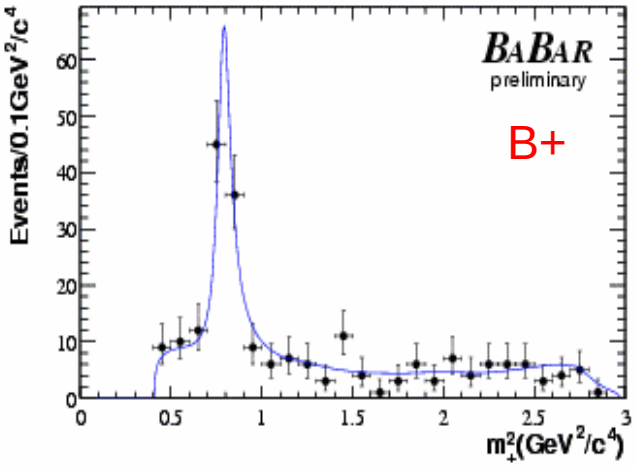
From the plot on the left, the DCS components are sensitive to γ, as well as the ρ(770)

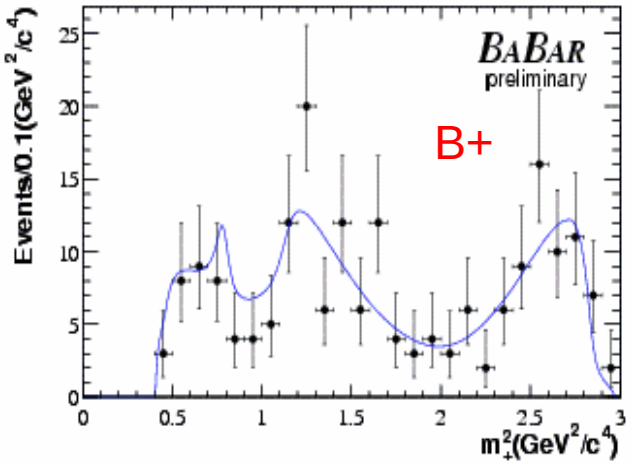
Although the DCS decay is highly suppressed, one have sensitivity on γ due to ρ(770), where the decay fraction $D^0 \rightarrow K_s$ ρ(770) is large. (22% from the fit fraction)

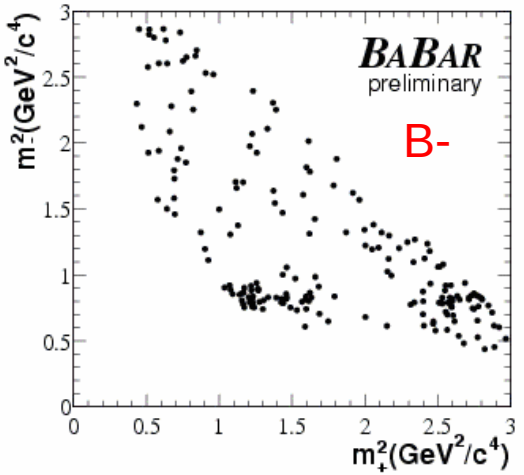
$B^- \to D^0 K^-$

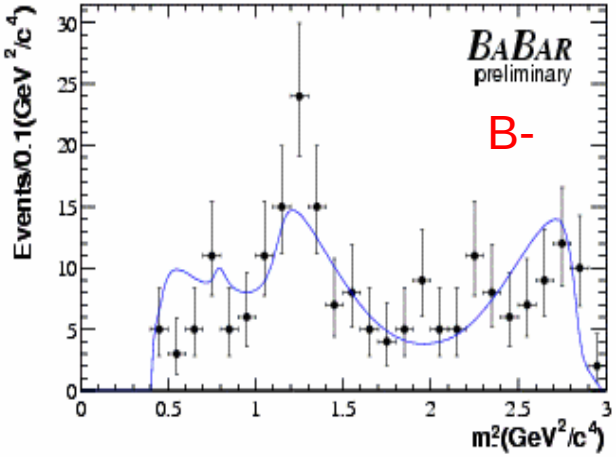
$$r_b = 0.106^{+0.056}_{-0.054}$$
$$d_b = 127^{+30}_{-34}$$
$$g = 66^{+33}_{-30}$$

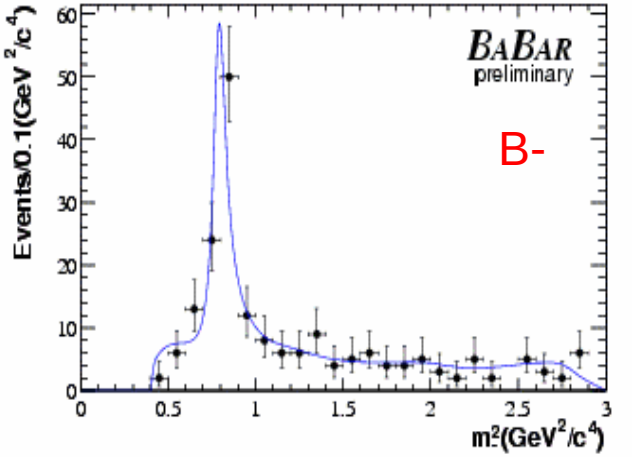










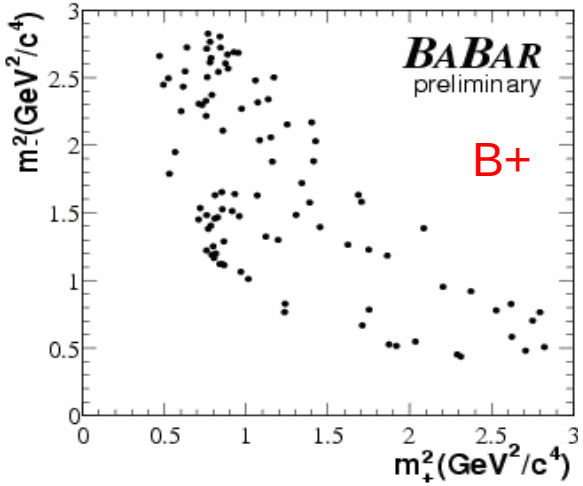


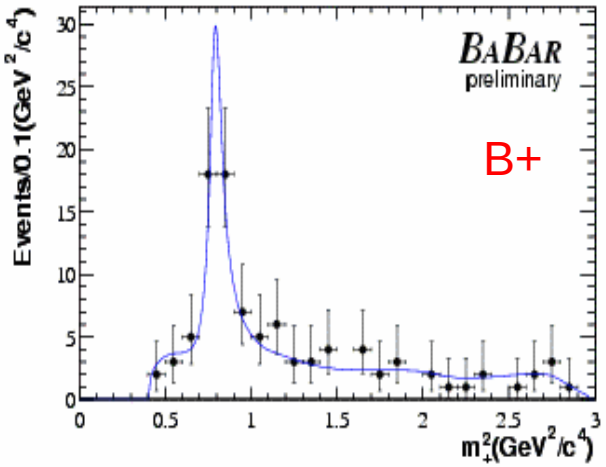
Dalitz projection for m_{ES} >5.272 GeV/c²

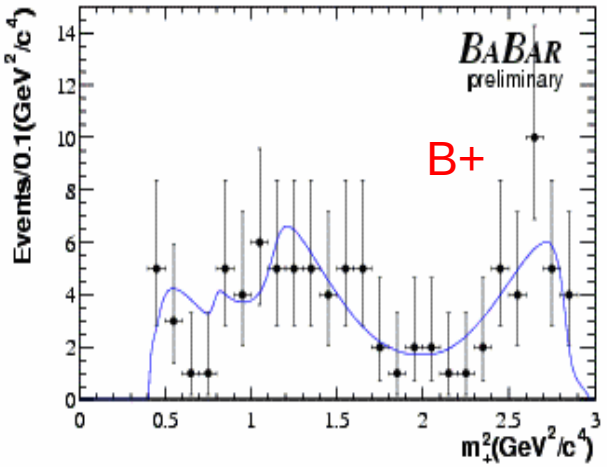
Signal plus background PDF superimposed

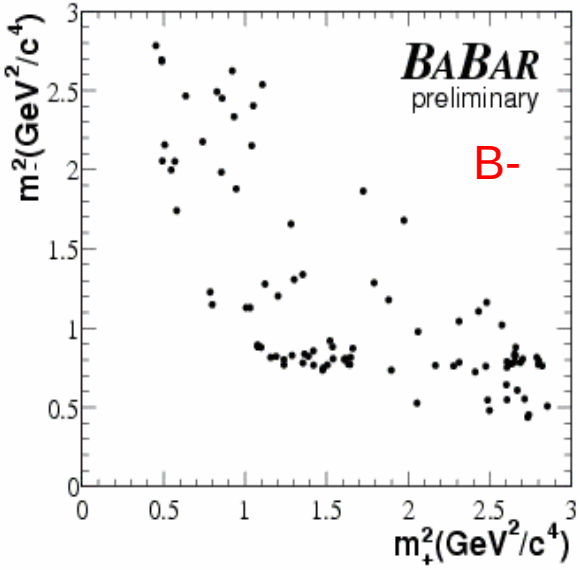
$B^- \to D^{*0} K^-$

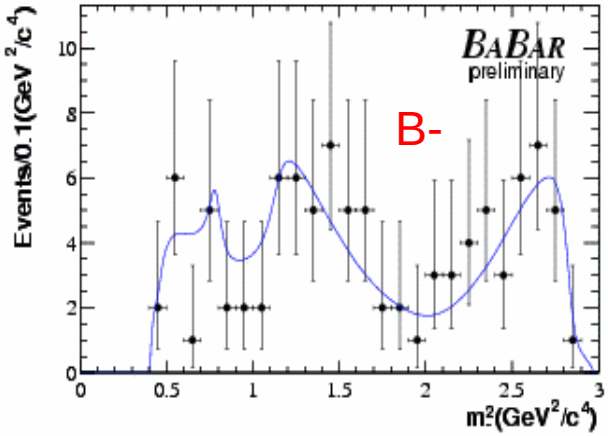
$$r_b^* = 0.130^{+0.083}_{-0.076}$$
$$d_b^* = 309^{+33}_{-46}$$
$$g = 120^{+37}_{-39}$$

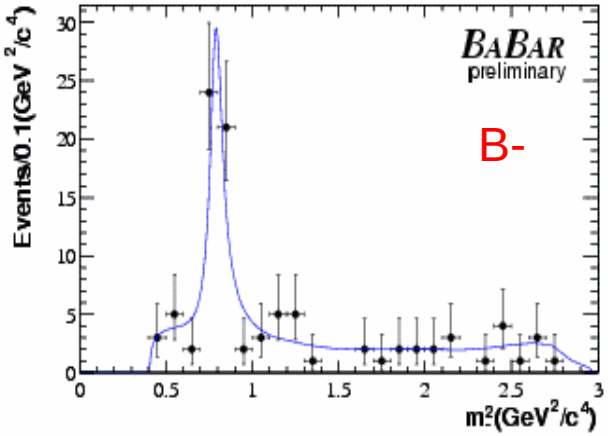










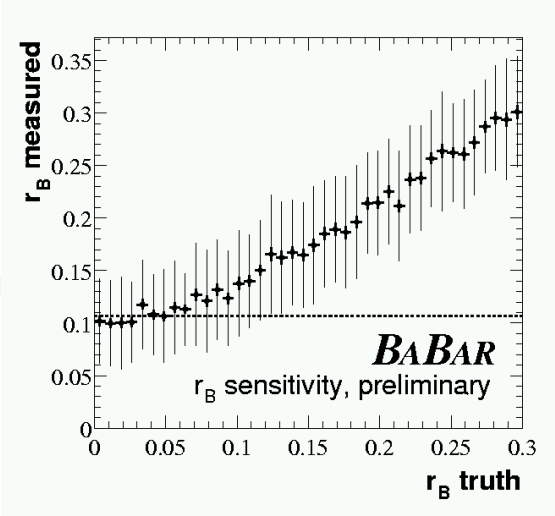


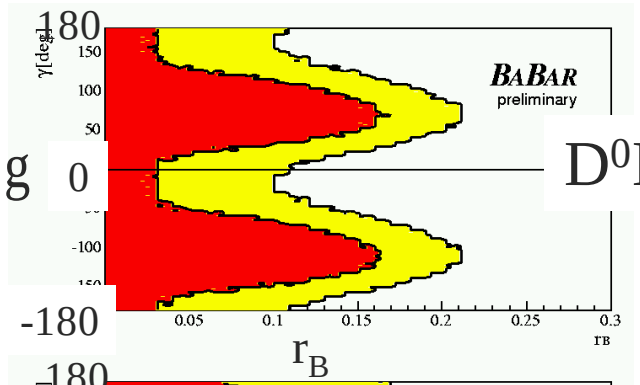
Dalitz projection for m_{ES} >5.272 GeV/c²

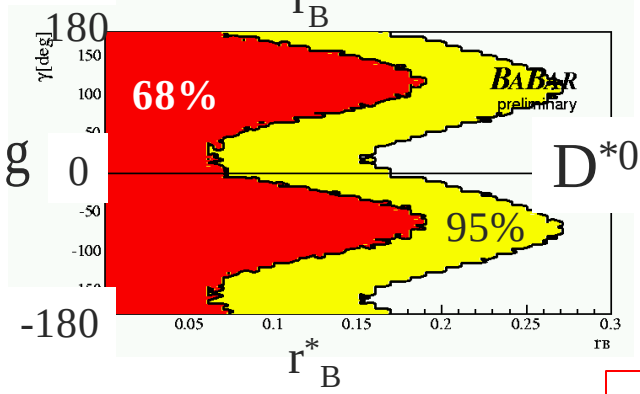
Signal plus background PDF superimposed

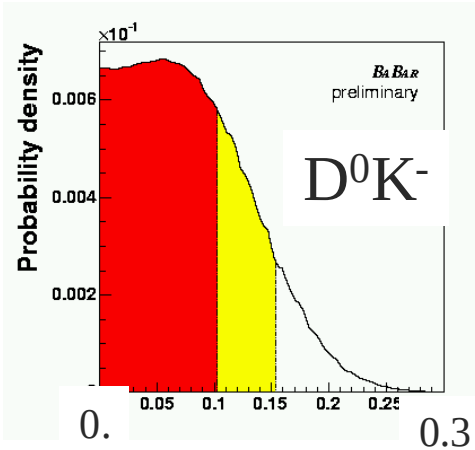
γ from $B^- \to D^{(*)0}[K_S\pi^+\pi^-]K^-$

With current statistics, no r_B sensitivity for r_B<0.10

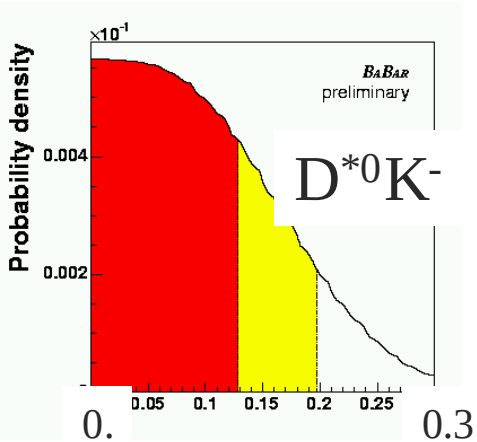








r_b<0.15 (95% CL)



r_b*<0.2 (95% CL)

$$d_B = (130 \pm 45 \pm 8 \pm 10)^o$$

$$d_B^* = (311 \pm 52 \pm 23 \pm 10)^o$$

Bayesian confidence regions

$$g = (88 \pm 41 \pm 19 \pm 10)^o$$

10^0 dalitz model systematics

Model systematics error

We tried the following (alternative) models to estimate the model systematics error

Alternative model:

1. Fitting with CLEO 10 resonances model
2. The nominal fit without σ(500)

10^0 model error

Uncertainty in Form Factor:

2. Using Relativisitic Breit-Wigner Form Factor instead of more accurate Gounaris-Sakurai parameterization for rho(770)
3. Set Blatt-Weisskopf penetration factor to 1.0

~2^0 model error

Uncertainty in mass and width of establish resonances.

4. Alternative parameterization for $f_0(1370)$ from WA 102 experiment.
5. Shifting K*(892) mass by +1MeV

Uncertainty in amplitude and phase.

6. Vary DCS K*(892) amplitude and phase

~2^0 model error

We take 10^0 as the model systematics

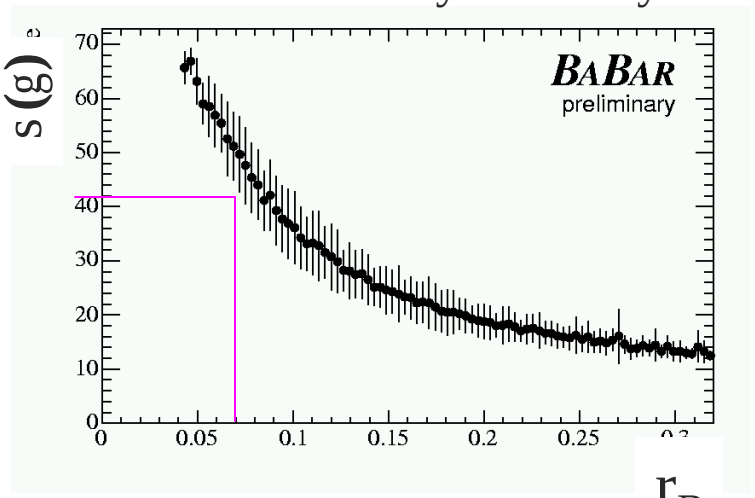
Other systematics error

	$B^- \to D^0 K^-$	$B^- \to D^{*0} K^-$
Uncertainty in background dalitz shape:	$\sim 7^0$	$\sim 3^0$
Uncertainty in mES, DE, F PDF shape:	$\sim 5^0$	$\sim 17^0$
Uncertainty in Efficiency:	$\sim 3^0$	$\sim 3^0$
Uncertainty in dalitz amplitude and phase:	$\sim 2^0$	$\sim 6^0$
Uncertainty in R(wrong sign tagging rate):	$\sim 2^0$	$\sim 3^0$
total	$\sim 10^0$	$\sim 19^0$

Conclusion

- B-→D^0K- dalitz plot analysis is one of the promising method to measure CKM γ
- We constraint the r_b<0.15 in the DK mode and r_b*<0.2 in the D*K mode, while Belle observed large value of r_b
- We measured the CKM γ to be $\gamma = (88 \pm 41 \pm 19 \pm 10)^o$ degrees, the large statistical error is due to small r_b value.

Toy MC study



- In addition, the dalitz plot analysis on the D*→D^0 π provide a new insight on charm meson spectroscopy

- The END!

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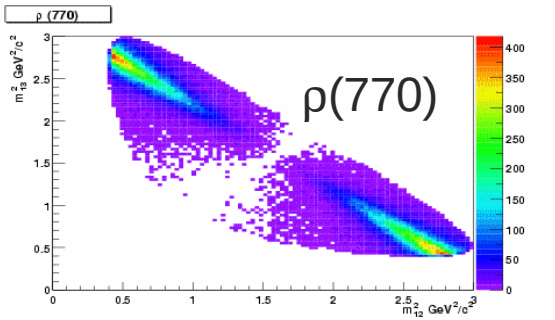
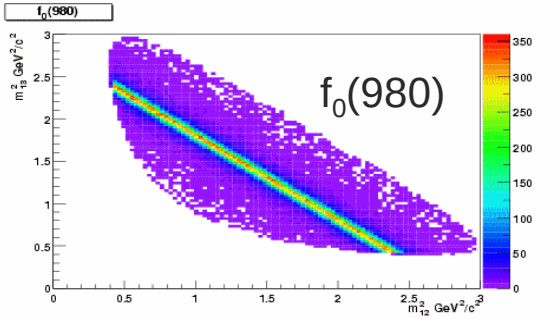
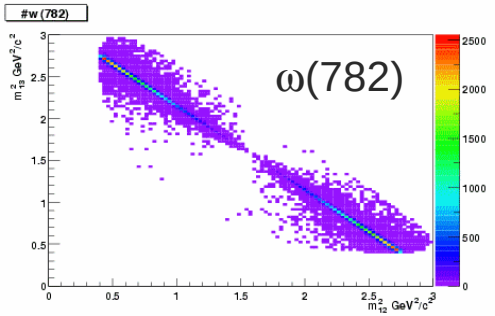
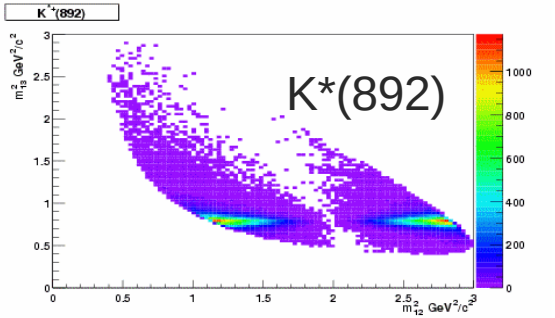
Backup slides
(the supporting materials)

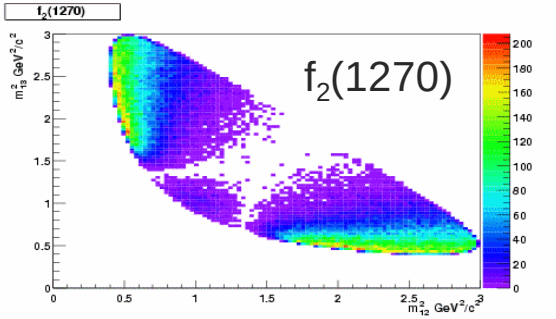
Dalitz plot at a glance

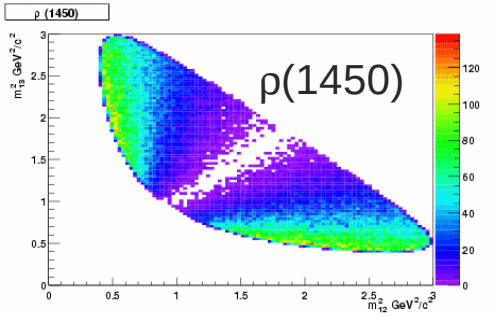


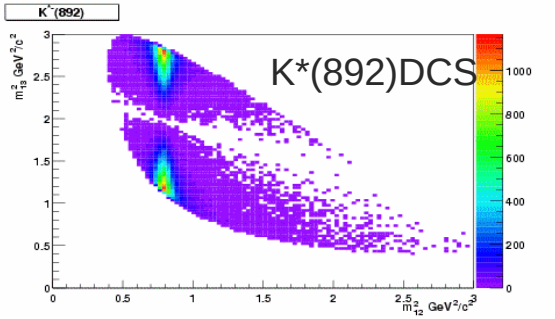


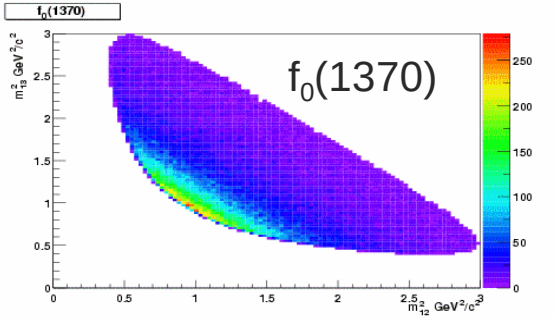


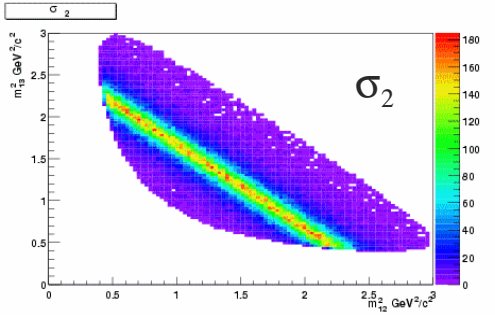












Dalitz plot at a glance