Studies of Charmless Two-Body, Quasi-Two-Body and Three-Body B Decays

Theresa J. Champion
University of Birmingham

for the *BABAR* Collaboration

Introduction

We consider channels mediated by $b \rightarrow u$ tree diagrams or $b \rightarrow d,s$ penguins

Two-body

$B^0 \rightarrow \pi^\pm\pi^\mp$
$B^0 \rightarrow K^\pm\pi^\mp$
$B^0 \rightarrow K^\pm K^\mp$

Quasi-two-body

$B^+ \rightarrow \omega h^+, \quad \omega \rightarrow \pi^0\pi^+\pi^-$
$B^0 \rightarrow \omega K^0_s$

$B^+ \rightarrow \eta' K^+, \quad \eta' \rightarrow \eta\pi^+\pi^-$ ($\eta \rightarrow \gamma\gamma$)
$B^0 \rightarrow \eta' K^0_s$

Three-body

($B \rightarrow 3h$, $h = \pi, K$)
$B^+ \rightarrow K^{*0}\pi^+$
$B^+ \rightarrow \rho^0 K^+$
$B^+ \rightarrow \rho^0\pi^+$
$B^0 \rightarrow \rho^\pm\pi^\mp$
$B^+ \rightarrow \pi^+\pi^+\pi^-$
$B^+ \rightarrow K^+\pi^+\pi^-$

These channels are interesting because:
- many have yet to be discovered
- some offer potential for CP violation studies:
  - Study of penguins, model validation
  - Direct CP violation
  - Indirect CP violation: measurement of α, β and γ

Analysis Overview

- Data Set:
  - 7.7 fb^{-1} at $\Upsilon(4S)$ (on resonance)
  - 1.2 fb^{-1} below $B\bar{B}$ threshold (off resonance)

- Analysis Method

  "Blind" : signal region hidden until analysis complete

  Cut-based (all modes)
  channel-dependent cuts, selected by optimising BR sensitivity

  Global Likelihood fit (Two-body modes)

- Analysis Details
  See *BaBar-CONF-00/14, BaBar-CONF-00/15*

- *Beam-energy-substituted mass* $m_{ES} = \sqrt{E^{*\,2}_{beam} - p^{*2}_{B}}$

- *Energy difference* $\Delta E = E^{*}_{B} - E^{*}_{beam}$

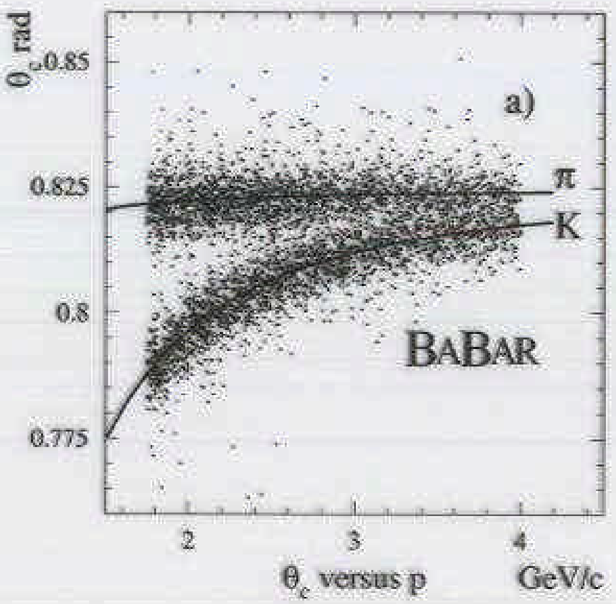
Event Selection: Kaon Identification

Excellent kaon identification is essential for the decay modes of interest

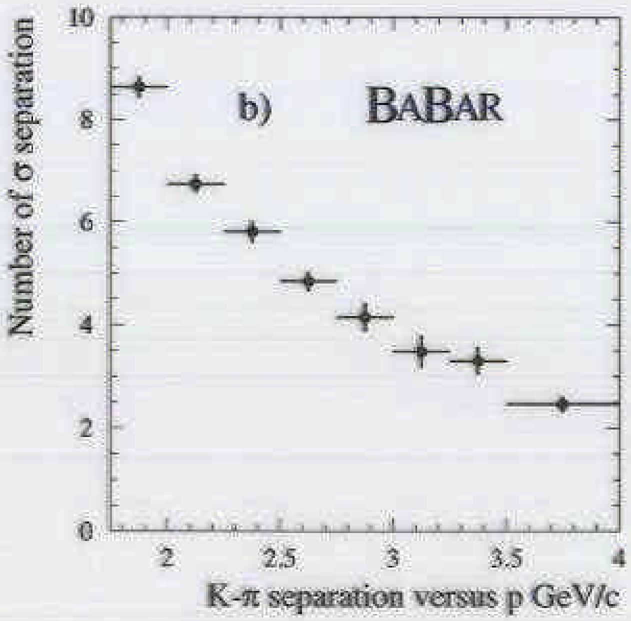
$$\text{separation} = \frac{\langle\theta(\pi)\rangle - \langle\theta(K)\rangle}{\langle\sigma_\theta\rangle}$$

DIRC (ring-imaging Cerenkov detector) :
Cerenkov angle θ_c
Drift Chamber: *dE/dx*
Silicon Vertex Tracker: *dE/dx*

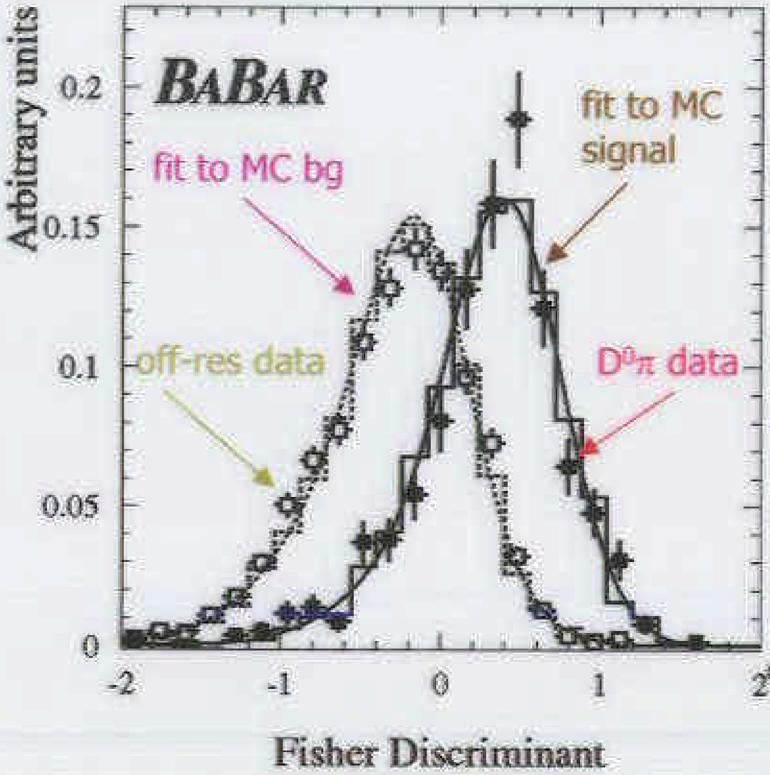
K/π separation >2σ at momenta up to 4GeV/c



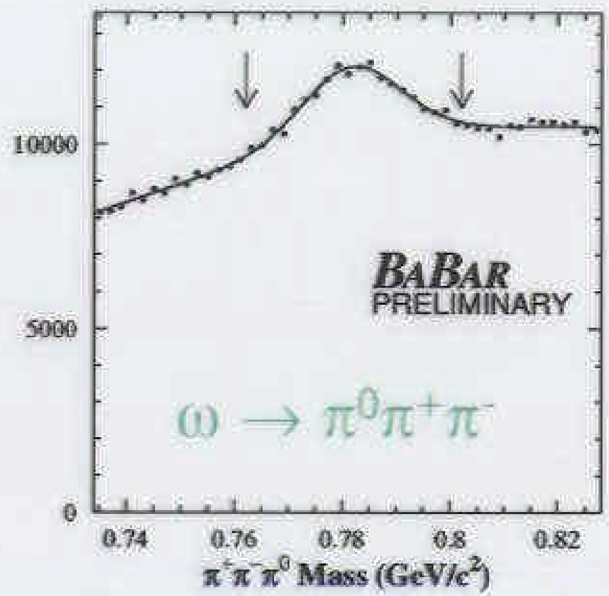
pure sample of
$D^* \to D^0\pi^+ \to (K\pi)\pi^+$



Event Selection: Quasi-two-body modes

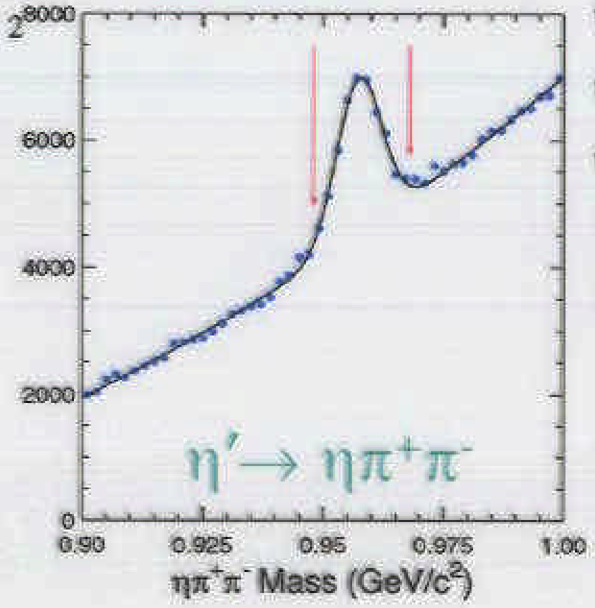


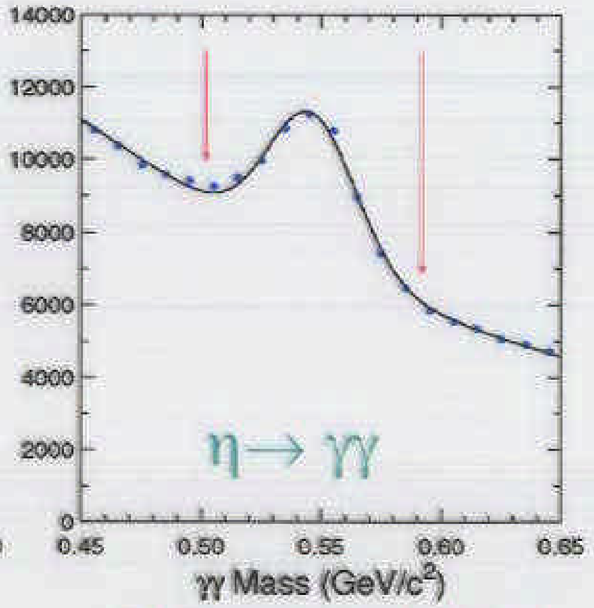
- $B^+ \rightarrow \omega h^+$
- $B^0 \rightarrow \omega K^0$
- $B^+ \rightarrow \eta' K^+$
- $B^0 \rightarrow \eta' K^0$



Background suppression:

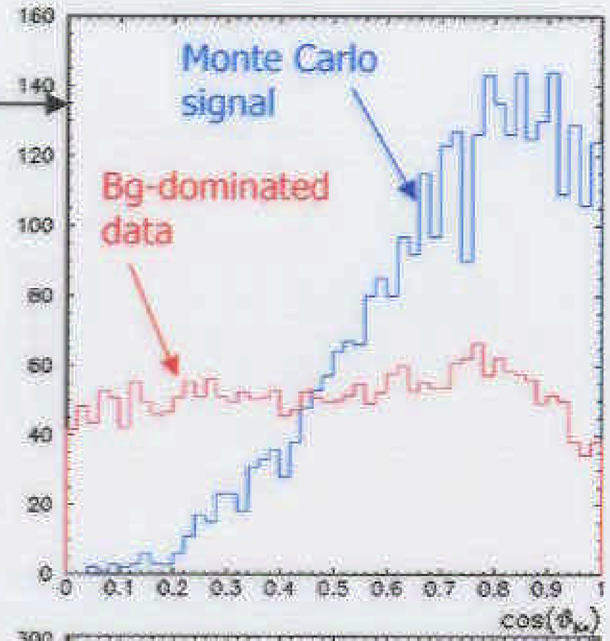
Fisher Discriminant
9 energy cones around
B decay axis





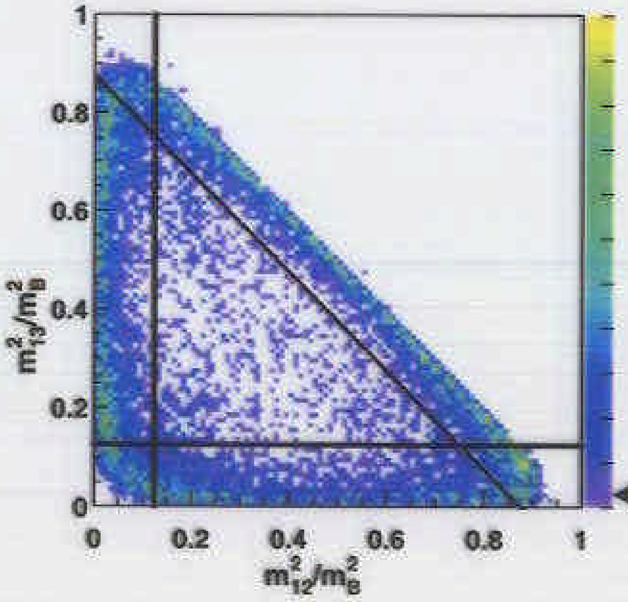
Event Selection: Three-body modes

ρ, K^{*0} helicity angle



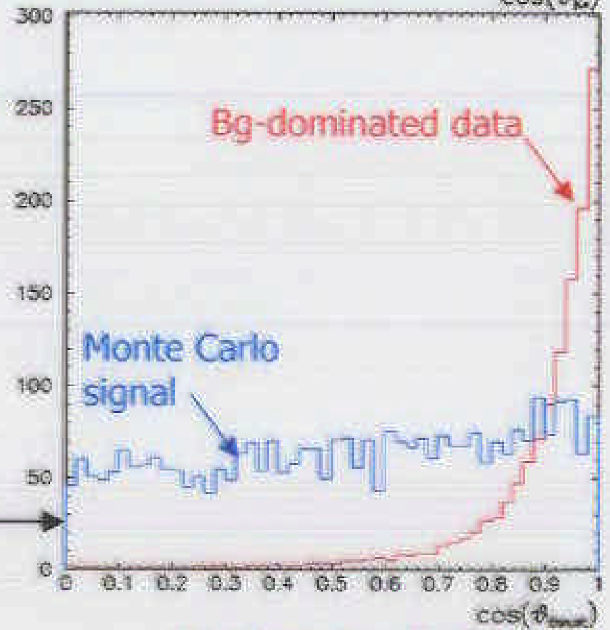
- $B^+ \to K^{*0}\pi^+$
- $B^+ \to \rho^0 K^+$
- $B^+ \to \rho^0 \pi^+$
- $B^0 \to \rho^{\pm}\pi^{\mp}$

- $B^+ \to \pi^+\pi^+\pi^-$
- $B^+ \to K^+\pi^+\pi^-$

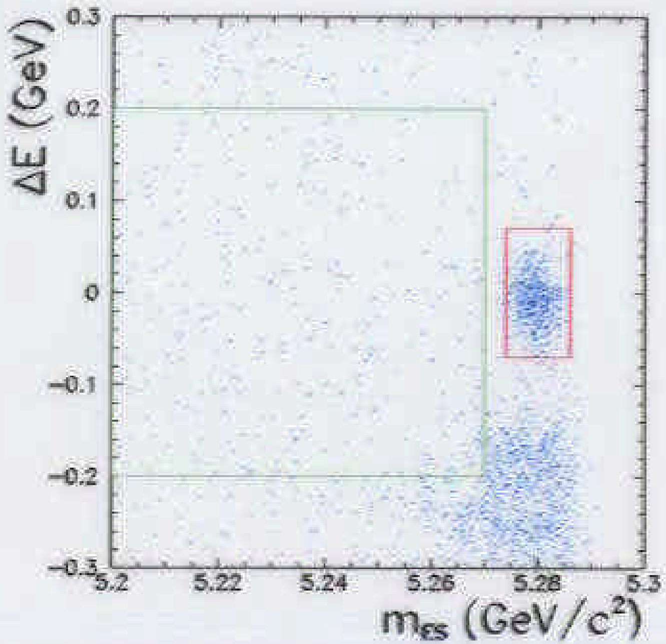


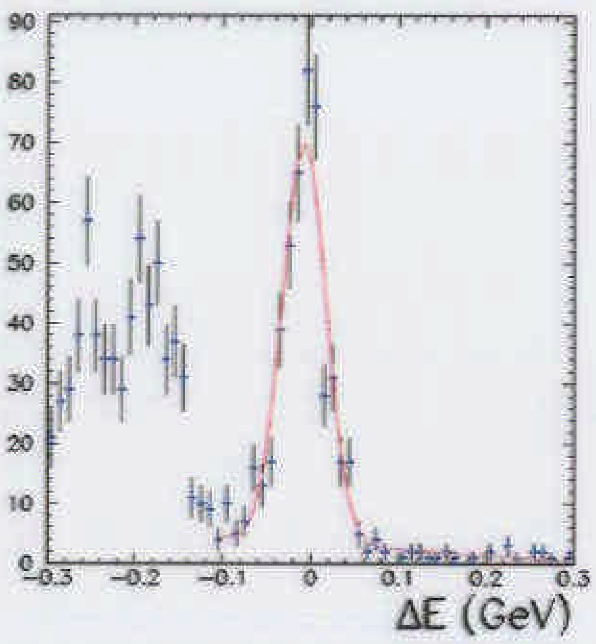
phase space cuts
J/ψ, D^0 veto

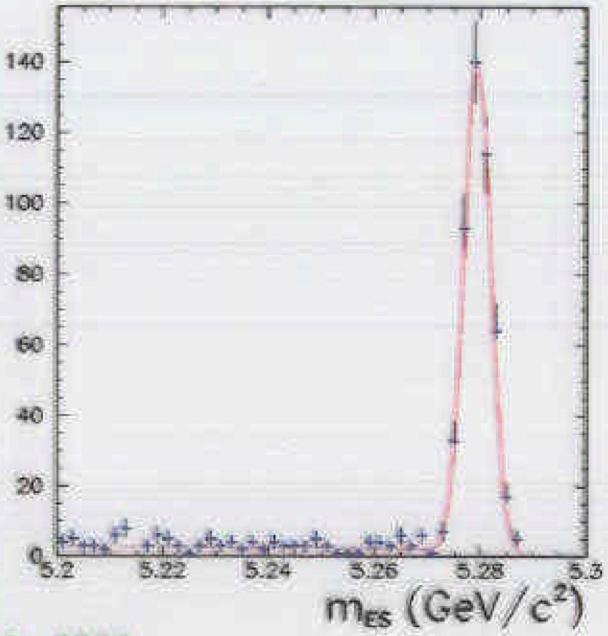
cosine angle between axes of B decay and rest-of-event



Calibration Modes







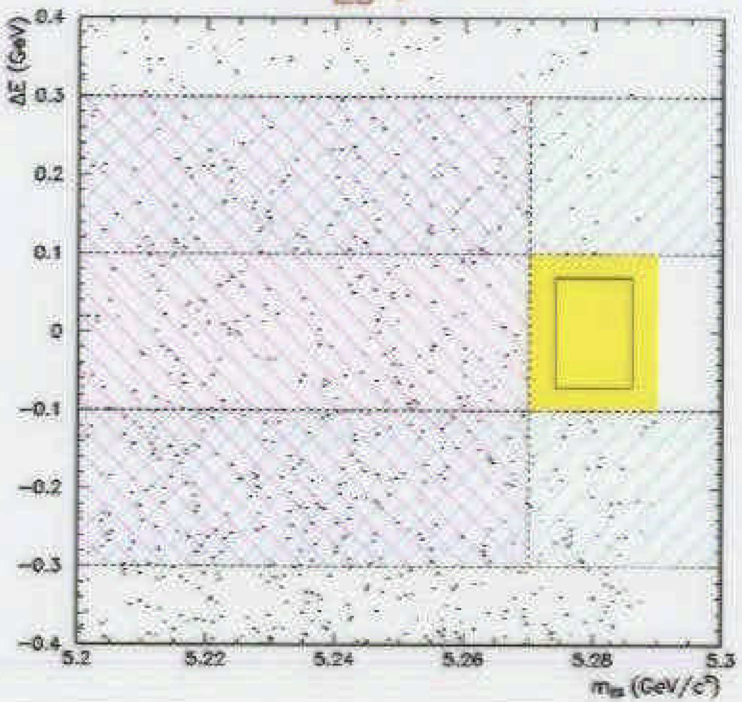
Measure BRs ($\times 10^{-4}$):

$B^+ \rightarrow \overline{D}^0\pi^+ \rightarrow (K\pi)\pi$
2.21 ± 0.11 (stat)
$[2.03 \pm 0.20]_{PDG}$

$B^+ \rightarrow \overline{D}^0\pi^+ \rightarrow (K\pi\pi^0)\pi$
6.79 ± 0.32 (stat)
$[7.37 \pm 0.84]_{PDG}$

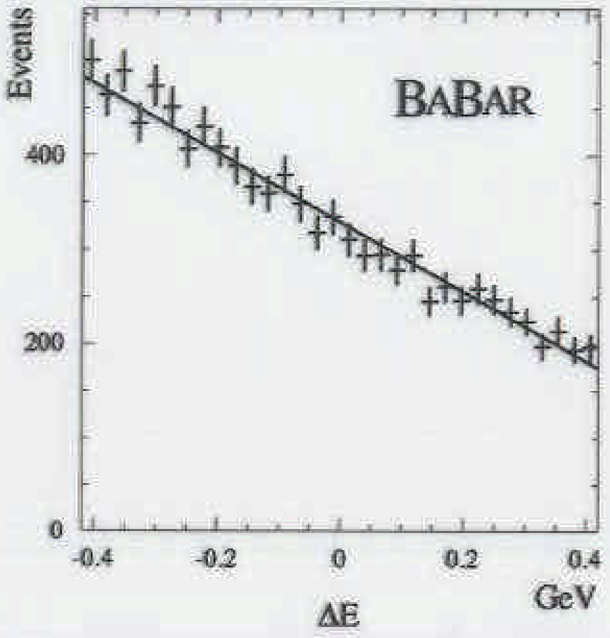
Background Characterisation

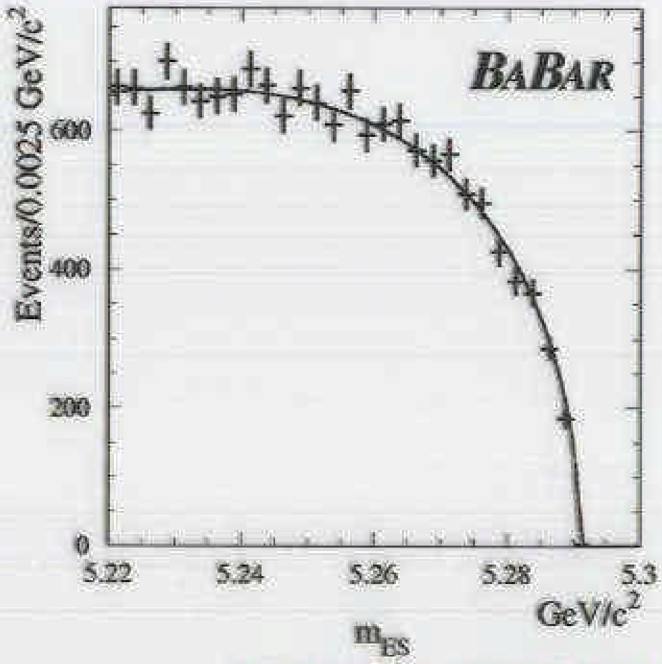
ΔE vs. m_{ES} plane



Measure number of events in : sidebands (N_2), extrapolating to signal region (N_1)

Find ratio
$\Re = N_1/N_2$





Linear fit to ΔE
Argus Function fit to m_{ES}

$$dN/dx = Ax\sqrt{(1-x^2)}\,\exp[-\,\xi(1-x^2)],$$
where $x = m_{ES}/E_{beam}$

Results: Quasi-two-body Modes

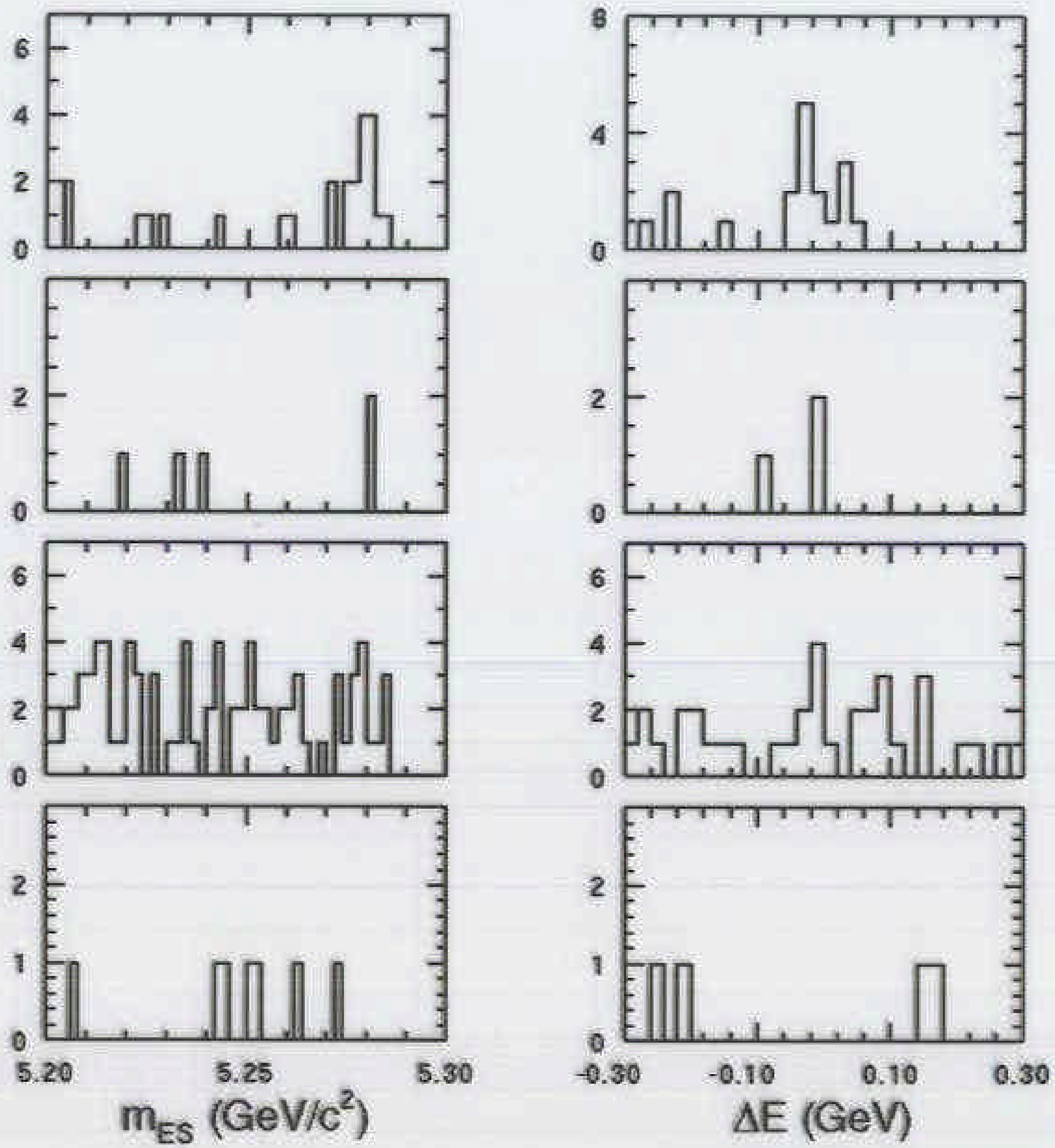
$$B = \frac{N_1 - \Re N_2}{N_B \varepsilon} = \frac{N}{N_B \varepsilon}$$

$N(\eta'_{\eta\pi\pi} K^{\pm}) = 12 \pm 4$

$N(\eta'_{\eta\pi\pi} K^0_S) = 1 \pm 1$

$N(\omega h^{\pm}) = 6 \pm 4$

$N(\omega K^0) = 0$



Results: Three-body Modes

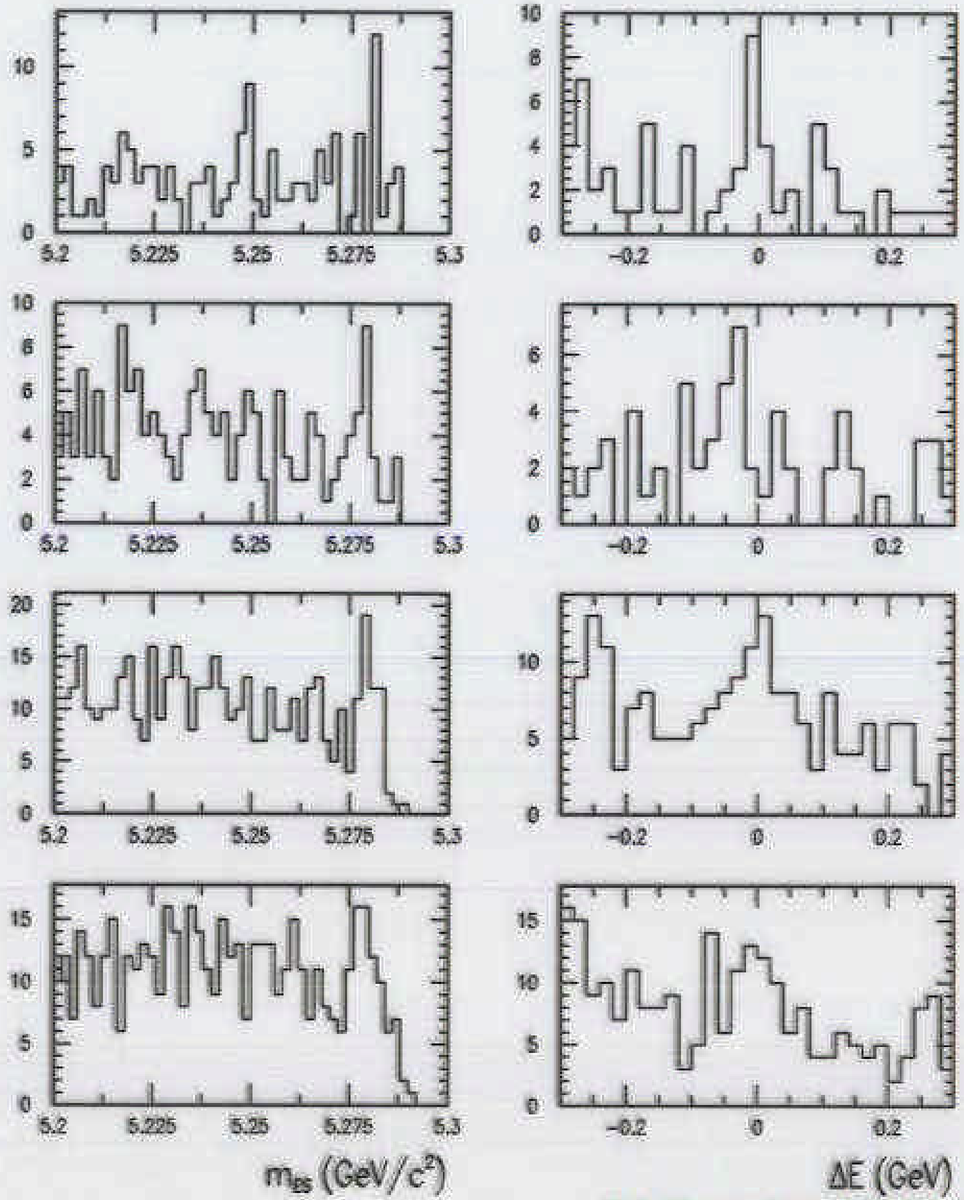
$$B = \frac{N_1 - \Re N_2}{N_B \varepsilon} = \frac{N}{N_B \varepsilon}$$

$N(K^{*0}\pi^{\pm}) = 10 \pm 5$

$N(\rho^0 K^{\pm}) = 11 \pm 5$

$N(\rho^0 \pi^{\pm}) = 25 \pm 8$

$N(\rho^{\pm}\pi^{\mp}) = 36 \pm 10$

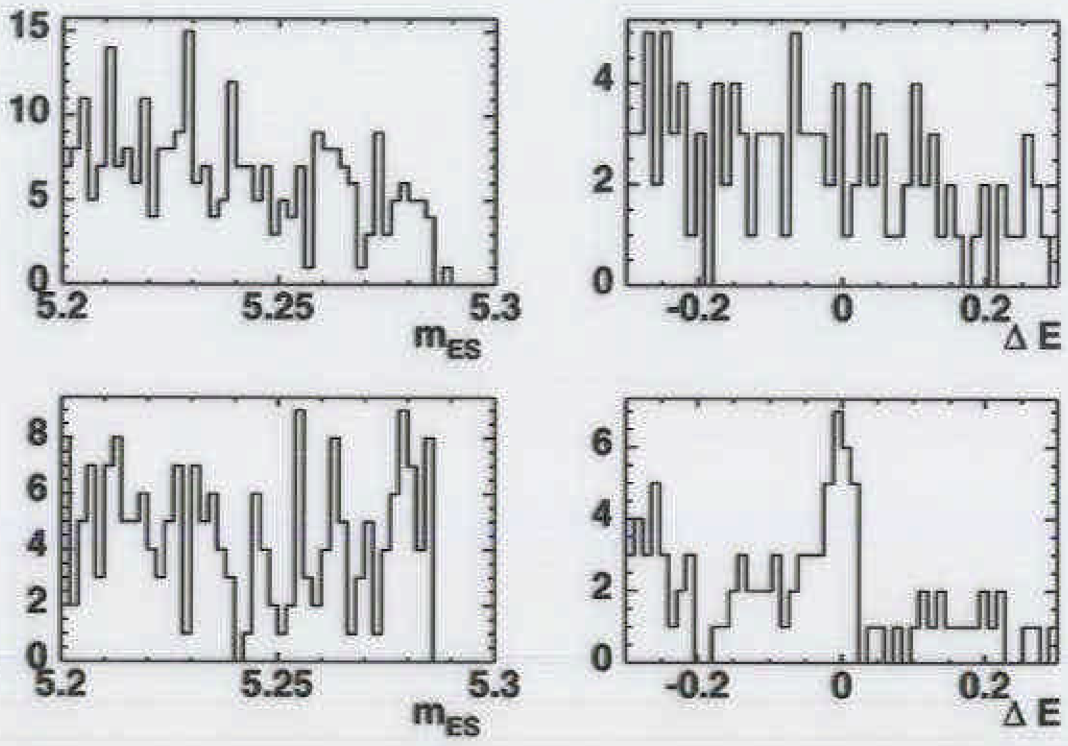


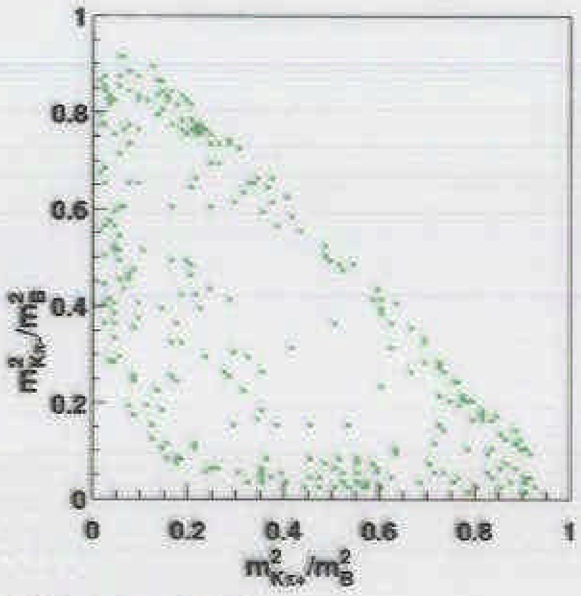
Results: Three-body Final States (non-resonant + higher resonances)

$$B = \frac{N_1 - \Re N_2}{N_B \varepsilon} = \frac{N}{N_B \varepsilon}$$

$N(\pi^+\pi^+\pi^-) = 5 \pm 6$

$N(K^+\pi^+\pi^-) = 19 \pm 6$



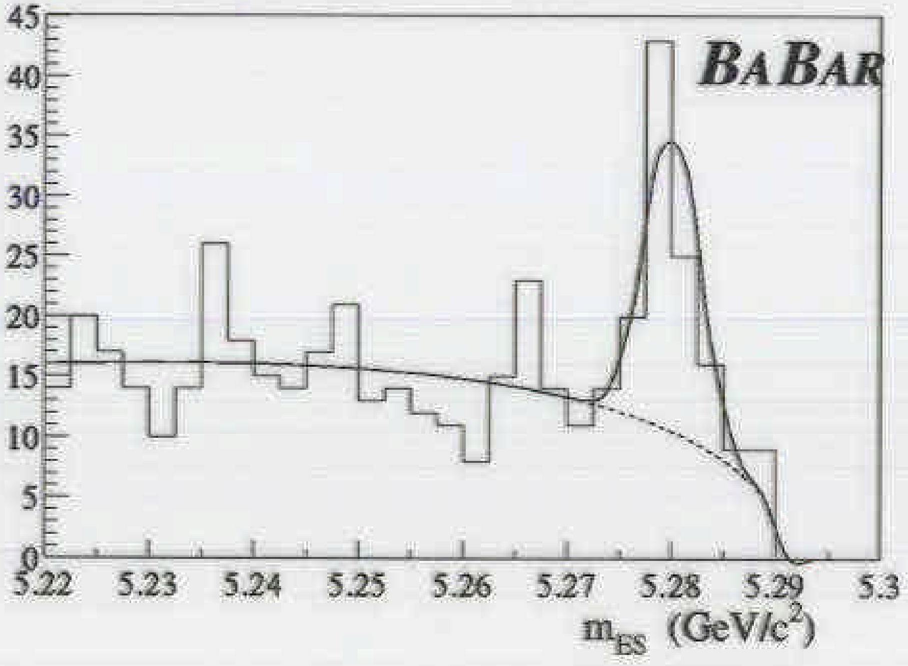


$K^+\pi^+\pi^-$ Dalitz plot

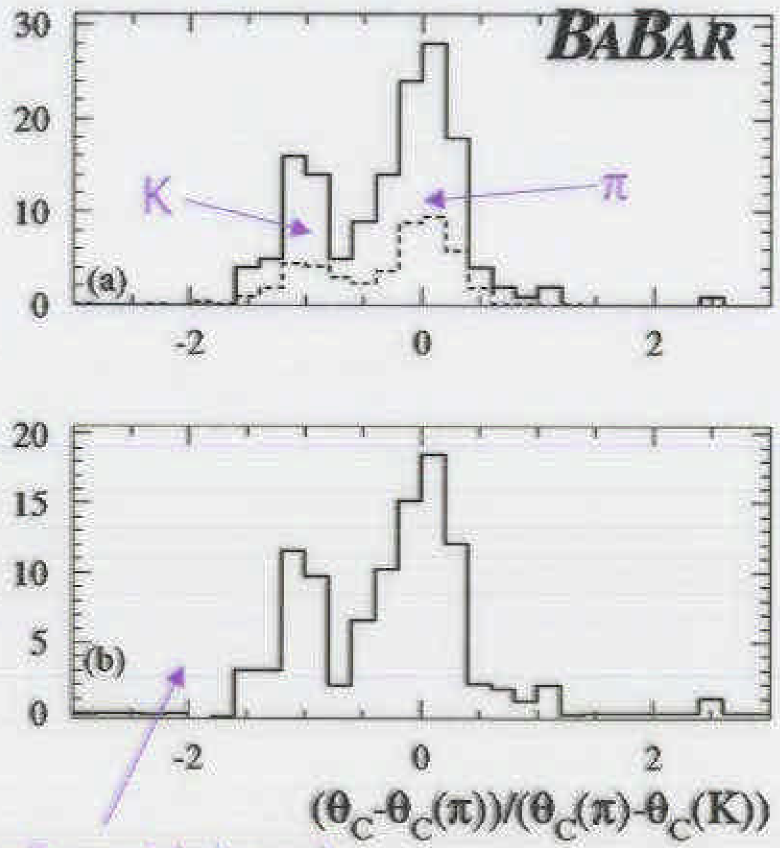
Cut-based $B^0 \to h^+h^-$ Analysis

Cut on event shape variables to reduce background
Signal yield from a fit to m_{ES} in the region $|\Delta E|<140$ MeV

signal for h^+h^-



evidence for kaons



after sideband subtraction

Cut-based Analysis with Kaon Selection

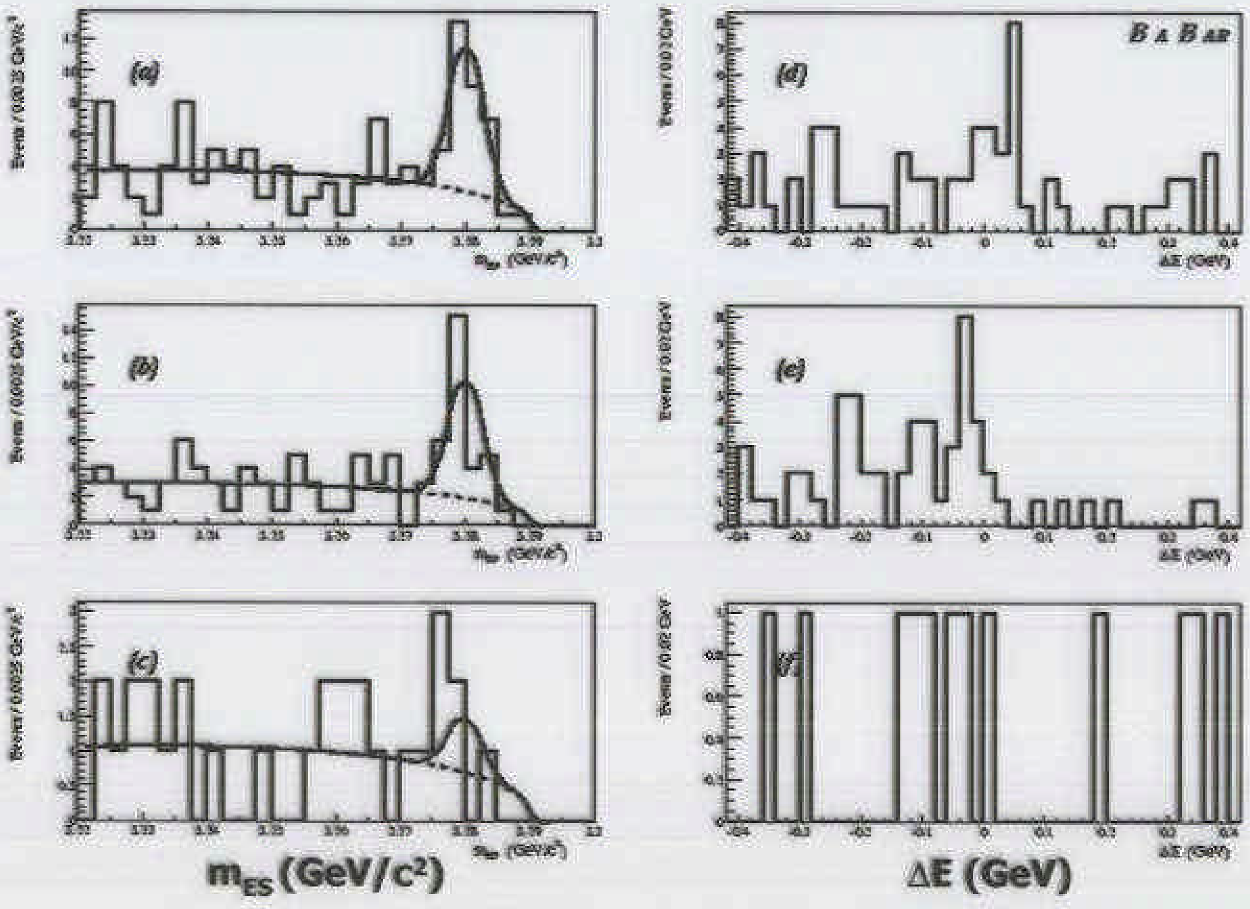
	Probability to be identified as		
Mode	$\pi\pi$	$K\pi$	KK
$\pi\pi$	0.853 ± 0.005	0.109 ± 0.008	0.0029 ± 0.0002
$K\pi$	0.121 ± 0.004	0.775 ± 0.006	0.051 ± 0.004
KK	0.0112 ± 0.0006	0.231 ± 0.008	0.704 ± 0.007

Fit mass distribution to determine signal yields

$N(\pi\pi) = 25 \pm 8$

$N(K\pi) = 26 \pm 8$

$N(KK) = 1 \pm 4$



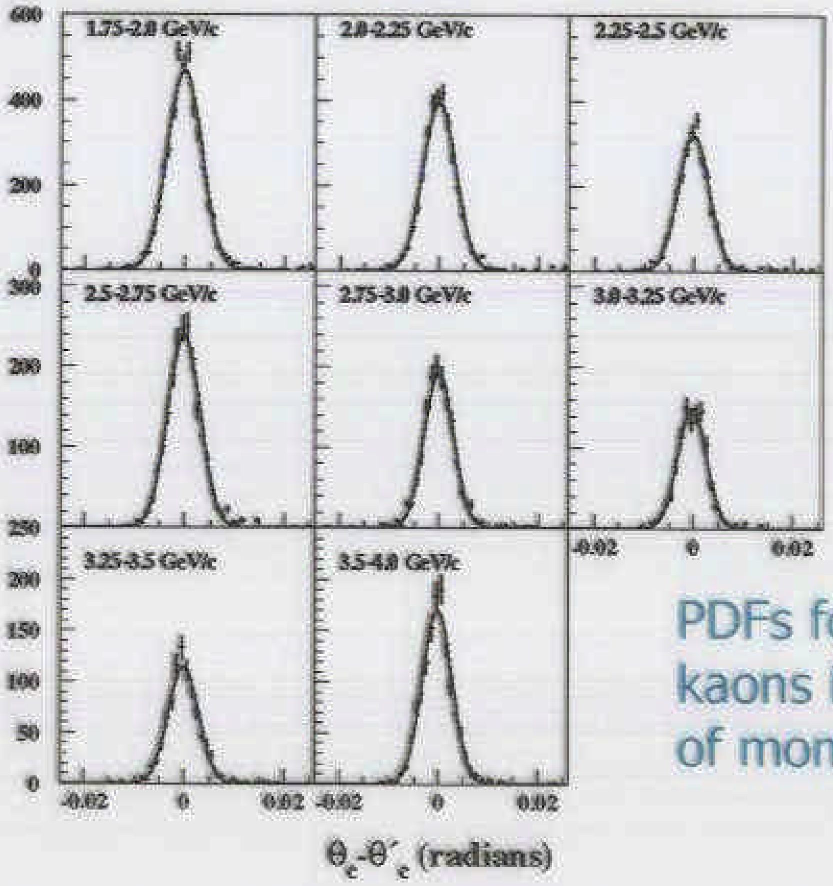
Likelihood Fit for Two-body Analysis

Global likelihood fit: using m_{ES}, ΔE, Fisher, Cerenkov angles for tracks

$$\mathcal{L} = e^{-N'} \prod_{i=1}^{N} \mathcal{P}_i(m_{ES}, \Delta E, \mathcal{F}, \theta_1, \theta_2 | N_{\pi\pi}, N_{K\pi}, N_{\pi K}, N_{KK}, N_{bkg})$$

to determine signal and background yields

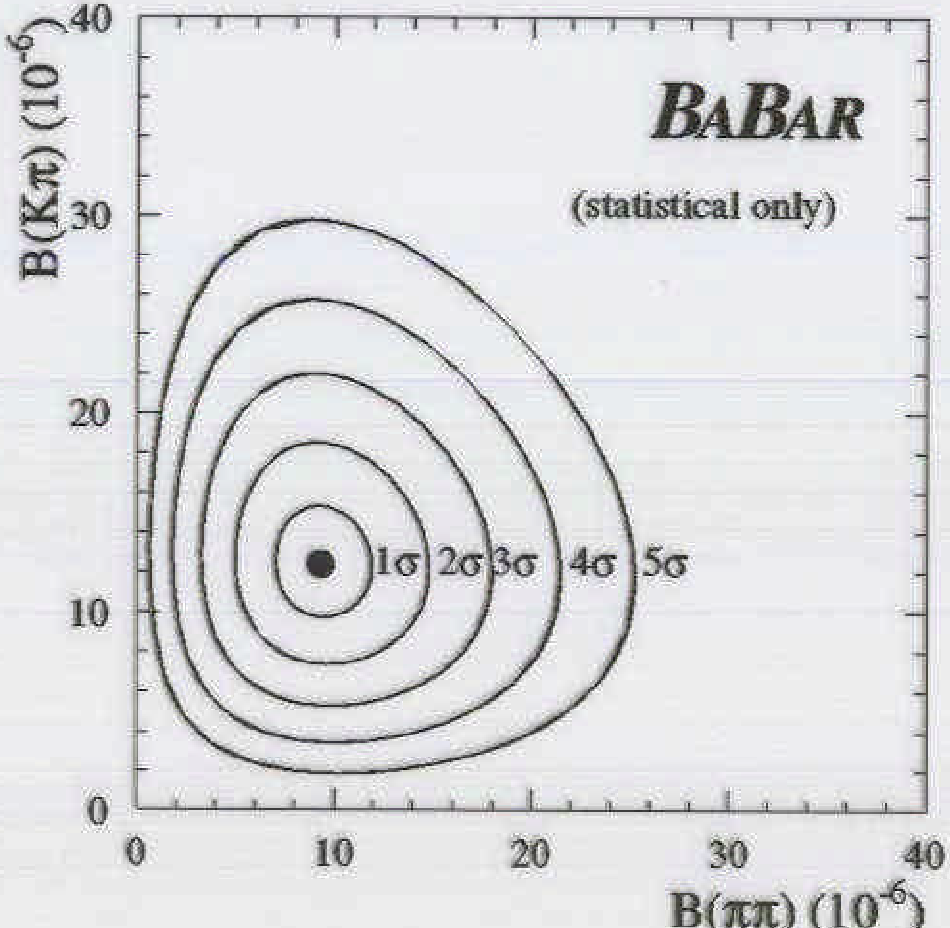
PDFs obtained from data where possible



PDFs for θ_c for kaons in 8 bins of momentum

Results: Two-body Analysis

Mode	N	BR(10^{-6})	σ
$\pi^{\pm}\pi^{\mp}$	29 ± 8	$9.3^{+2.6\,+1.2}_{-2.3\,-1.4}$	5.7
$K^{\pm}\pi^{\mp}$	38 ± 9	$12.5^{+3.0\,+1.3}_{-2.6\,-1.7}$	6.7
$K^{\pm}K^{\mp}$	7 ± 5	< 6.6	2.1



Summary of Results

We have provided several competitive measurements of BRs and upper limits, and anticipate further results in the near future:

	BaBar BR/10^{-6}	CLEO BR/10^{-6}
$\pi^\pm\pi^\mp$	$9.3^{+2.6}_{-2.3}{}^{+1.2}_{-1.4}$	$4.3^{+1.6}_{-1.4} \pm 0.5$
$K^\pm\pi^\mp$	$12.5^{+3.0}_{-2.6}{}^{+1.3}_{-1.7}$	$17.2^{+2.5}_{-2.4} \pm 1.2$
$K^\pm K^\mp$	< 6.6	<1.9
ωh^+	< 24	14.3 ± 3.6
ωK^0	< 14	< 21
$\eta'_{\eta\pi\pi}K^+$	$62 \pm 18 \pm 8$	80 ± 10
$\eta'_{\eta\pi\pi}K^0$	< 112	89 ± 18
$K^{*0}\pi^+$	< 28	< 16
$\rho^0 K^+$	< 29	< 17
$K^+\pi^+\pi^-$	< 66	< 28
$\rho^0\pi^+$	< 39	10.4 ± 3.4
$\pi^+\pi^+\pi^-$	< 22	27.6 ± 8.4
$\rho^\pm\pi^\mp$	$48.5 \pm 13.4^{+5.8}_{-5.2}$	< 41

All analyses are statistics-limited. Main sources of systematics are: tracking eff.: 2.5% /track; π^0 eff.: 5% /π^0; Monte Carlo statistics: 2-7%