Analysis of the decay $B^{\pm} \to K^{\pm}\pi^{\mp}\pi^{\pm}$ at the BABAR Experiment

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BABAR Collaboration

Introduction

- Present results from the completed analysis:
  - Measurements of the exclusive branching fractions of $B^{\pm}$ decays to $K^{\pm}\pi^{\mp}\pi^{\pm}$ final states
- Introduce current work:
  - Amplitude analysis of $B^{\pm}$ decays to the final state $K^{\pm}\pi^{\mp}\pi^{\pm}$

Physics Motivation

- $B^\pm$ decays to the final state $K^\pm\pi^\mp\pi^\pm$ via intermediate resonances can be used to search for direct CP violation
- Measurements of the branching fractions of the intermediate resonances can be compared with predictions from hadronic models (QCD Factorisation etc.), e.g.
  - W. N. Cottingham, *et al.*, J. Phys. **G28** (2002) 2843
  - M. Beneke and M. Neubert, Nucl. Phys. **B675** (2003) 333-415
  - C. Chiang *et al.*, Phys. Rev. D **69** (2004) 034001
  - R. Aleksan, *et al.*, Phys. Rev. D **67** (2003) 094019
- Study of these decays can also help to clarify the nature of the resonances involved, not all of which are well understood

General Analysis Issues 1 - Kinematic Variables

- $e^+e^- \to \Upsilon(4\mathrm{S}) \to B\overline{B}$
  - B produced almost at rest in $\Upsilon(4\mathrm{S})$ frame
- Use beam energy to improve resolution
- Energy and momentum conservation give:
  - $\Delta E = E^*_B - E^*_{beam}$ $\to 0$ for signal
  - $m_{ES} = \sqrt{E^{*2}_{beam} - p^{*2}_B}$ $\to m_B$ for signal

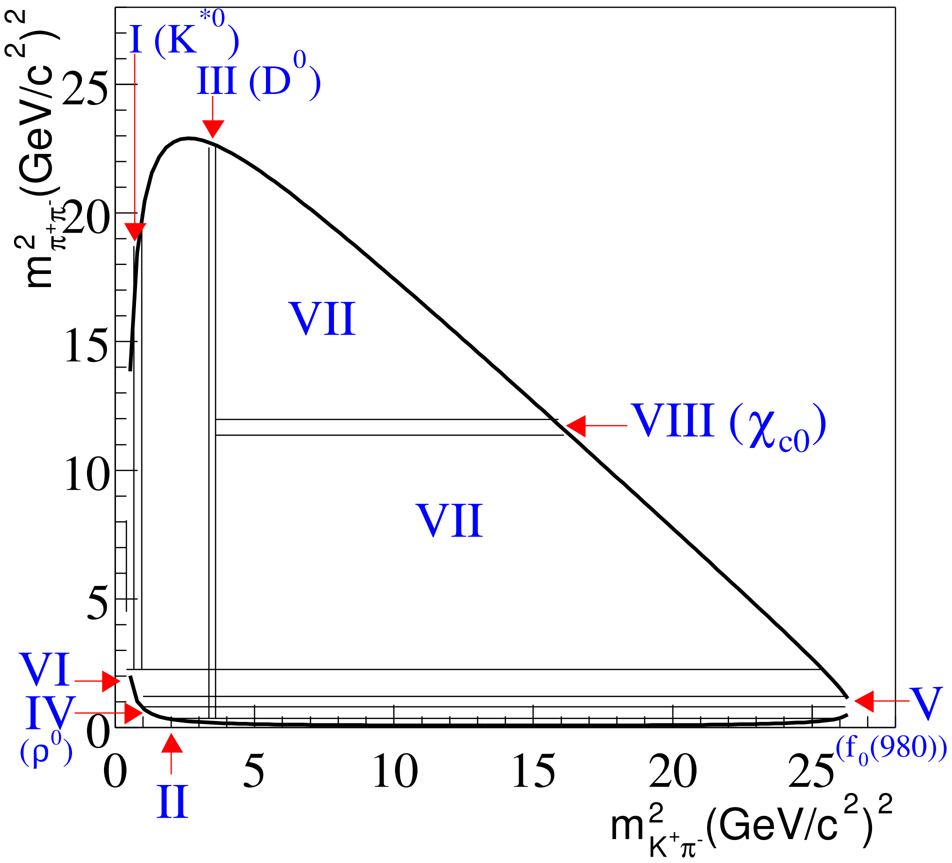
General Analysis Issues 2 - Event Topology

- B produced almost at rest in $\Upsilon(4\mathrm{S})$ frame
  - B decays are isotropic
- $q\bar{q}$ decay products can have considerable momentum
  - Continuum (udsc) decays are jet-like
- Form a Fisher Discriminant of topological variables
  - This is a linear combination of variables
  - Gives greater separation between hypotheses than selecting on the variables alone

$B^{\pm} \rightarrow K^{\pm}\pi^{\mp}\pi^{\pm}$ Exclusive Branching Fraction Overview

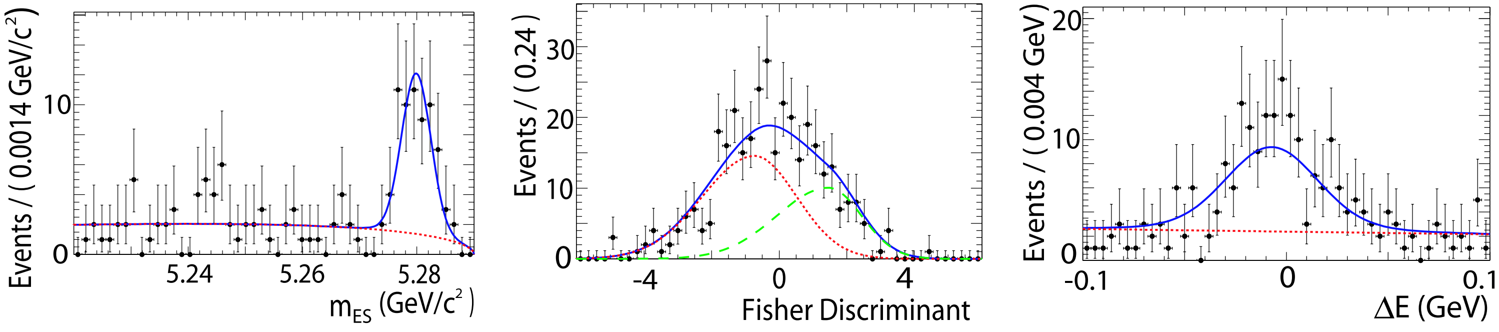
- Investigate resonance composition
- Divide Dalitz Plot into regions
- Measure yields to each region
- Maximum Likelihood analysis with PDFs for m_{ES}, ΔE, Fisher
  Parameterised separately for each region
- Then interpret yields in regions as BFs of resonances using coupled resonance model considering interferences as a systematic
- Dataset: 61 million $B\overline{B}$ pairs

Regions of the Dalitz Plot



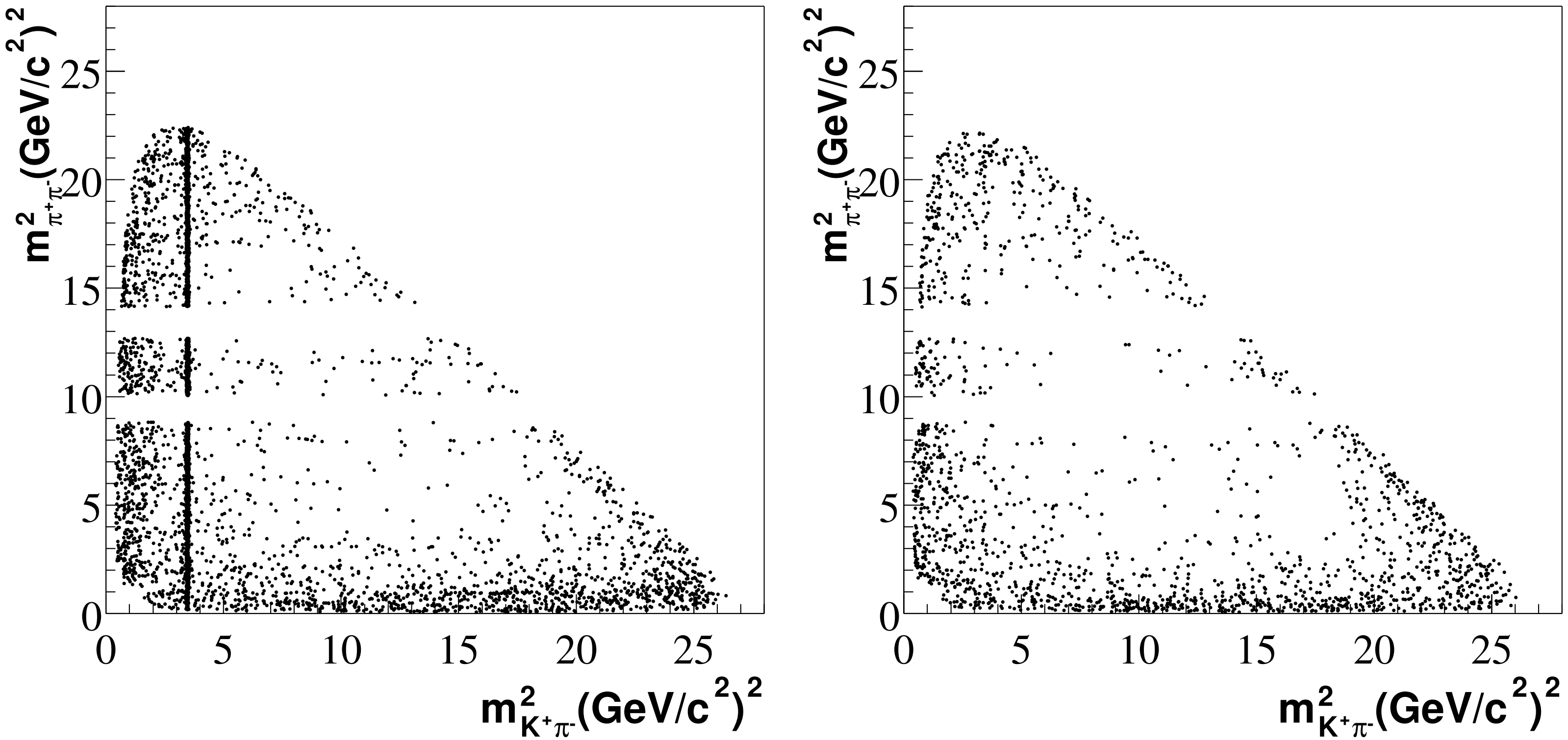
Fit Variable Projection Plots

- Histograms shown are for Region I (K^{*0})
- Histograms have likelihood ratio cut on other two variables
- Fit projections: total background signal



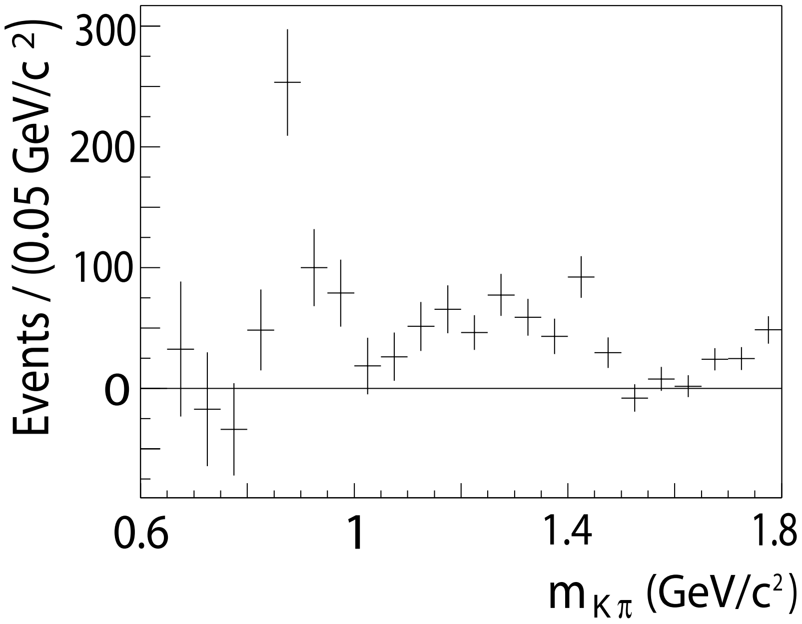
Dalitz Plots

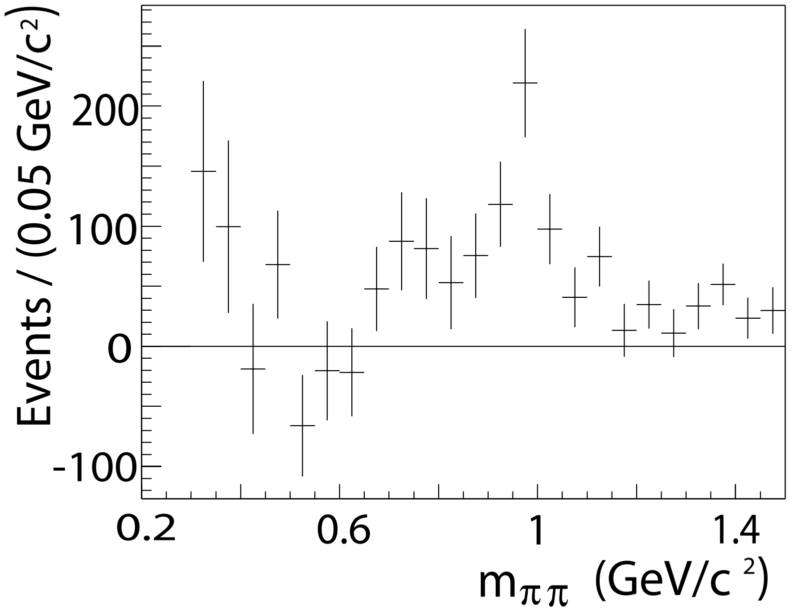
- Plots have likelihood ratio cut in ΔE & Fisher
- Left-hand plot has signal-like cut in m_{ES}
- Right-hand plot has background-like cut in m_{ES}



Mass Projections

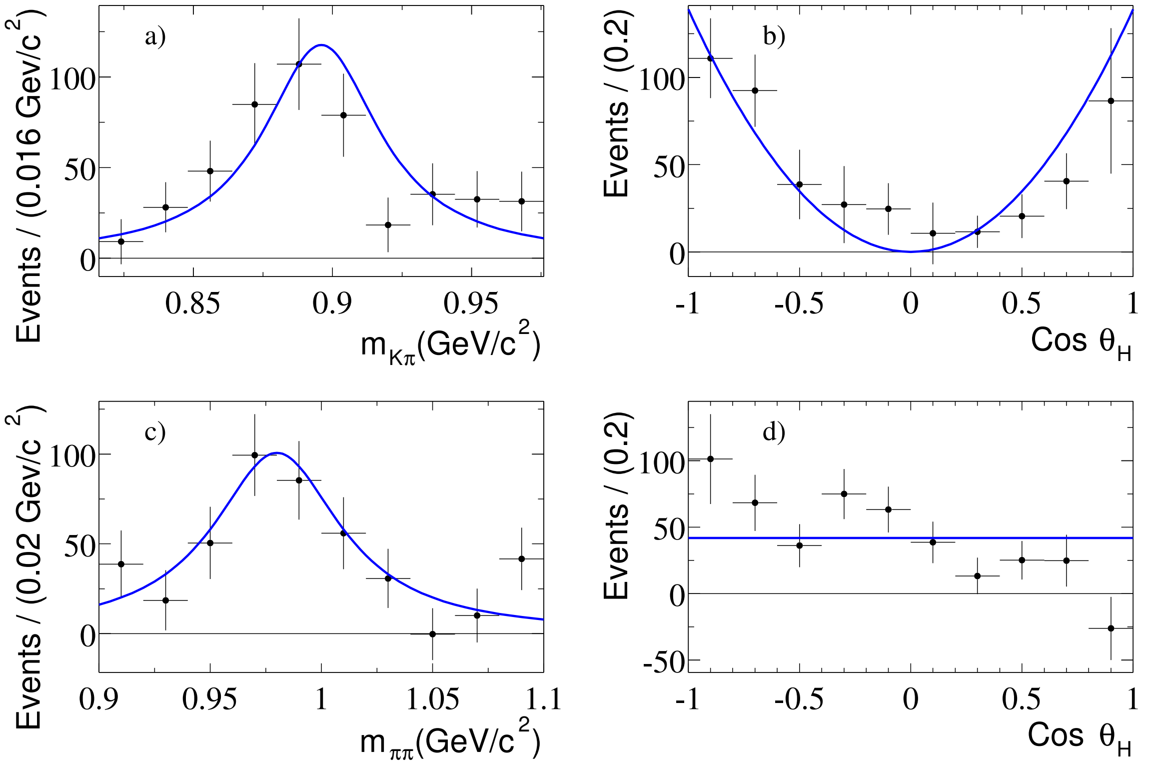
- Background subtracted projections of $m_{K\pi}$ & $m_{\pi\pi}$





Mass & Helicity Angle Projection Plots

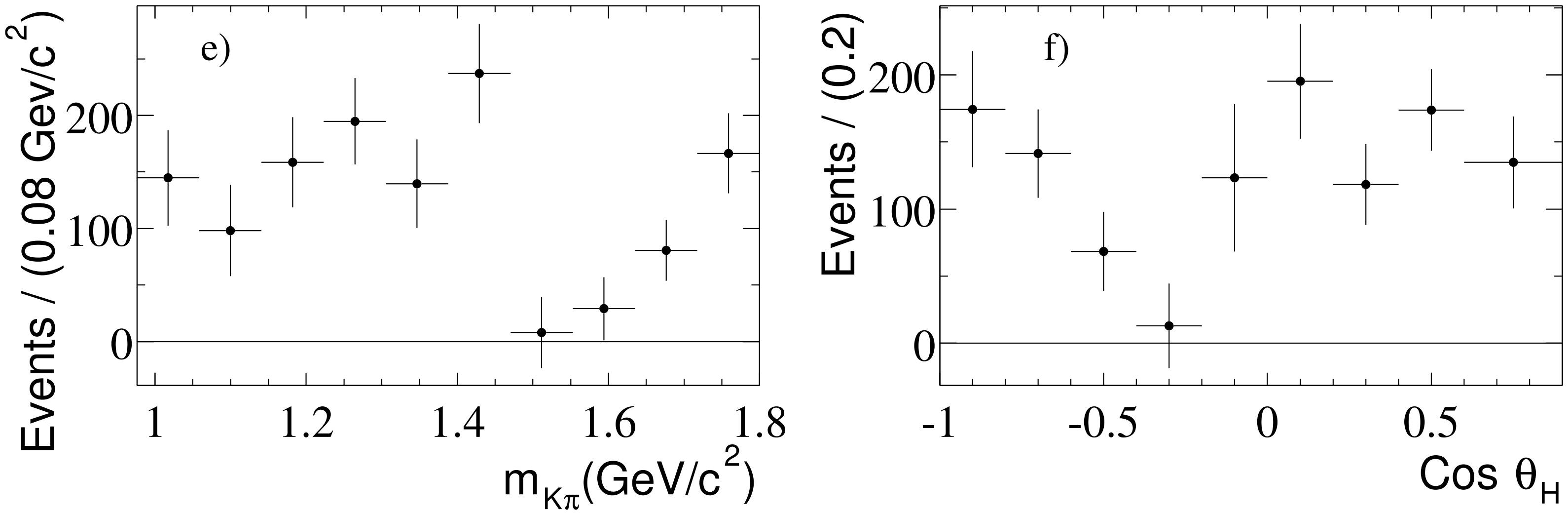
- Histograms have likelihood ratio cut
- Have been background subtracted & efficiency corrected



Upper plots - Region I (K^{*0}); Lower Plots - Region V ($f_0(980)$)

The "higher K^{*0}" region

- Structure cannot be explained by any single resonance
- Up to $m_{K\pi} = 1.6\ \mathrm{GeV}/c^2$ shows similar structure to that observed on LASS for $K_0^{*0}(1430)$
  - D. Aston *et al.*, Nucl. Phys. **B296** (1988) 493



Branching Fractions

Channel	BF ($\times 10^{-6}$)	Errors ($\times 10^{-6}$)			
		Stat	Sys	Model	Interference
$K^{*0}\pi^+, K^{*0} \to K^+\pi^-$	10.3	± 1.2	± 0.7	$^{+0.4}_{-2.5}$	± 0.6
"higher K^{*0}" $\pi^+, K^{*0} \to K^+\pi^-$	25.1	± 2.0	± 2.9	$^{+9.4}_{-0.5}$	± 4.9
$\bar{D}^0\pi^+, \bar{D}^0 \to K^+\pi^-$	184.6	± 3.2	± 9.7	-	-
$\rho^0 K^+, \rho^0 \to \pi^+\pi^-$	3.9 (< 6.2)	± 1.2	$^{+0.3}_{-0.6}$	$^{+0.3}_{-3.2}$	± 1.2
$f_0(980)K^+, f_0 \to \pi^+\pi^-$	9.2	± 1.2	± 0.6	$^{+1.2}_{-1.9}$	± 1.6
"higher f" $K^+, f \to \pi^+\pi^-$	3.2 (< 12)	± 1.2	± 0.5	$^{+5.8}_{-2.4}$	± 1.5
Non resonant	5.2 (< 17)	± 1.9	$^{+0.8}_{-1.8}$	$^{+3.3}_{-7.5}$	± 6.4
$\chi^0_{c0}K^+, \chi^0_{c0} \to \pi^+\pi^-$	1.5	± 0.4	± 0.1	-	-

- Systematic errors are large since the exact nature of the contributions to the Dalitz Plot and their interferences are unknown
- "higher K^{*0}" means any combination of $K_0^{*0}(1430), K_2^{*0}(1430), K_1^{*0}(1680)$
- "higher f" means any combination of $f_2(1270), f_0(1370), f_0(1430)$

$B^{\pm} \to K^{\pm}\pi^{\mp}\pi^{\pm}$ *Exclusive BF Conclusions*

- Measured BFs with statistical significances $> 5\sigma$ for:
  - $B^{\pm} \to K^{*0}(896)\pi^{\pm}$
  - $B^{\pm} \to$ "higher K^{*0}" $\pi^{\pm}$
  - $B^{\pm} \to f_0(980)K^{\pm}$
  - $B^{\pm} \to \chi_{c0}K^{\pm}$
  - $B^{\pm} \to D^0\pi^{\pm}$
- 90% CL upper limits for $B^{\pm} \to \rho^0 K^{\pm}$, $B^{\pm} \to$ "higher f" $K^{\pm}$
- First tight limit on non–resonant contribution
- $K^{*0}(896)$ result larger than expected by QCD factorization
- Analysis documented in hep-ex/0308065 and submitted to Physical Review D

Amplitude Analysis

- Greater statistics should allow the possibility of a more thorough treatment:
  - Full Dalitz Plot, or Amplitude Analysis
  - Complete treatment of interferences between the various resonances – should greatly reduce the large systematic uncertainties on the results for the sub decay modes
  - Measure amplitude magnitudes and phases $\rightarrow$ Branching Fractions, Charge Asymmetries and CP violation parameters
- This is what we are working on at the moment.
- Sian will tell you more in the next talk...