Analysis of the Decay $B^{\pm} \to K^{*\pm}\pi^0$ ($K^{*\pm} \to K^{\pm}\pi^0$) at BABAR

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Motivation

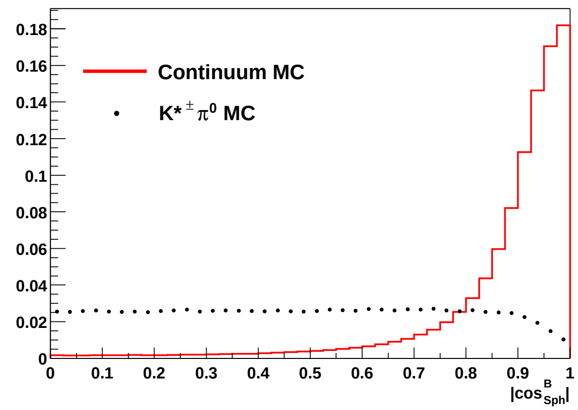
Why $B^{\pm} \to K^{*\pm}\pi^0$?

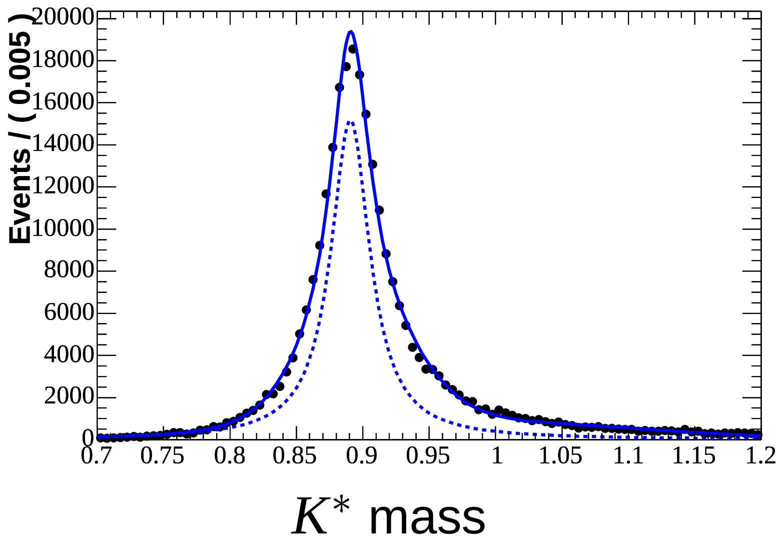
- Prospects for *direct* CP violation. $\Gamma(B^+ \to K^{*+}\pi^0) \neq \Gamma(B^- \to K^{*-}\pi^0)$.
- As yet unmeasured.
- Challenging - small BF $\mathcal{O}(10^{-6})$, two $\pi^0 s \to$ large backgrounds.
- Aim - Measure Branching Fraction for $B^{\pm} \to K^{*\pm}\pi^0 (K^{*\pm} \to K^{\pm}\pi^0)$ and Direct *CP* Asymmetry. $\mathcal{A}_{CP} = \frac{\Gamma(B^+ \to K^{*+}\pi^0) - \Gamma(B^- \to K^{*-}\pi^0)}{\Gamma(B^+ \to K^{*+}\pi^0) + \Gamma(B^- \to K^{*-}\pi^0)}$

- Overview of this talk:
  - Background characterisation.
  - Composition of ML fit. Validation.
  - Systematics, blind results.
  - Outlook.

Event selection

- Use $82\,fb^{-1}$ collected on $\Upsilon(4S)$, $\simeq 88$ million B^+B^- pairs.
- Reduce data set by preselecting events.
- Loose selection on π^0 quality.
- $0.1 < M_{\pi^0} < 0.16\,\mathrm{GeV}/c^2$.
- $E_\gamma > 0.03\,\mathrm{GeV}$.
- $0 < LAT_\gamma < 0.6$.





- Use particle ID information from DIRC and DCH to select Kaons.
- K^* mass selection - $0.8 < M_{K^*} < 1.0\,\mathrm{GeV}/c^2$.
- Use event shape variables to reject background
- $|\cos(\theta^B_{Sph}) < 0.9|$
- To reduce multiplicity, 'best candidate' selection is made using π^0information.

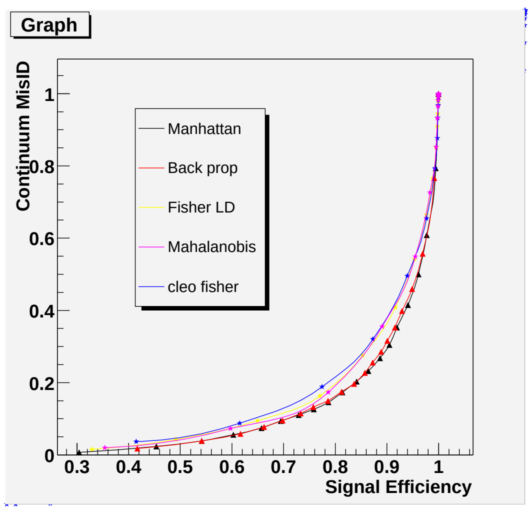
Continuum Fighting

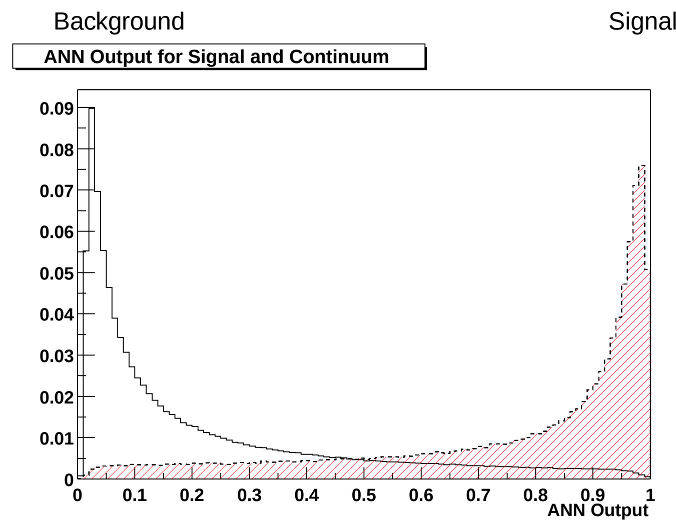
- Light quark (u, d, s, c) continuum production is by far our biggest background.
- Construct a discriminating variable to efficiently identify signal B candidates.
- Must exhibit low correlations with other fit variables.

- Two types considered:
  - Linear - Fisher, Mahalanobis.
  - Non-linear - Artficial neural network (ANN).
- Suitability based on *discriminating power* and *simplicity*.
- All inputs variables are event shape variables.

Continuum Fighting

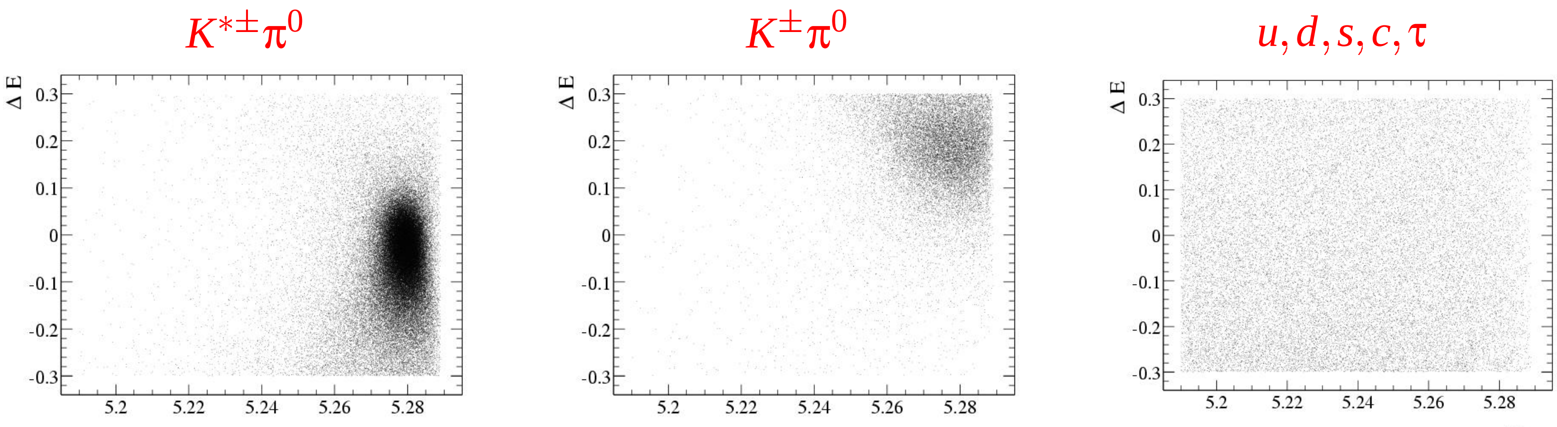
- Three inputs ultimately used:
  - $L_0 = \sum_{i}^{roe} p_i$
  - $L_2 = \sum_{i}^{roe} p_i \times \frac{1}{2}(3\cos^2(\theta_i) - 1)$
  - $TFlv$, the multivariate output of the BABAR tagging algorithm.



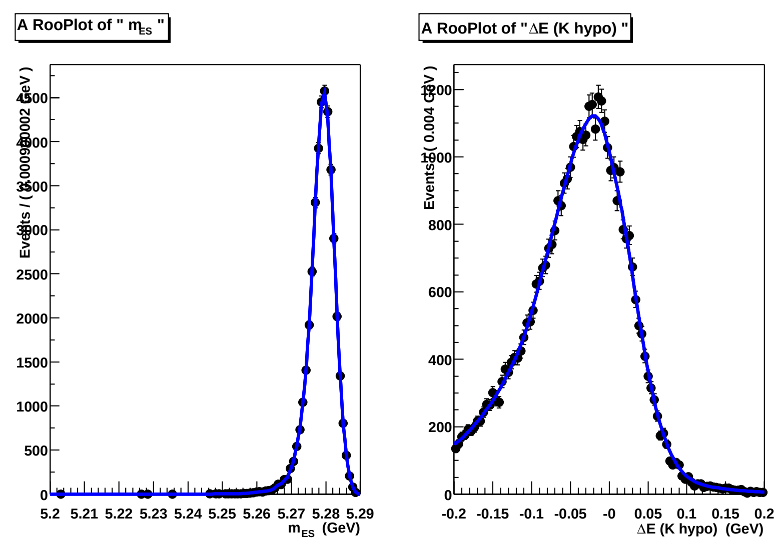


- The ANN consistently outperforms the linear discriminator.
- The final ANN architecture is a 3 layer perceptron with 6 hidden nodes, trained using 'Manhattan' updating. At 60% signal efficiency we reject 95% of continuum events.

Composition of Maximum Likelihood Fit



- Fit signal yields from data using maximum likelihood (ML) fit, interpret BF and asymmetry.
- PDFs formed from MC. Compose likelihood.
- $\mathcal{L} = e^{-N_{exp}} (N_{exp})^{N} \prod_{i=1}^{N} \mathcal{P}_i$
- ANN + two quantities, ΔE and m_{ES} are used in fit .
- ΔE 'energy difference'.
- m_{ES} 'beam-energy substituted mass'.



Backgrounds

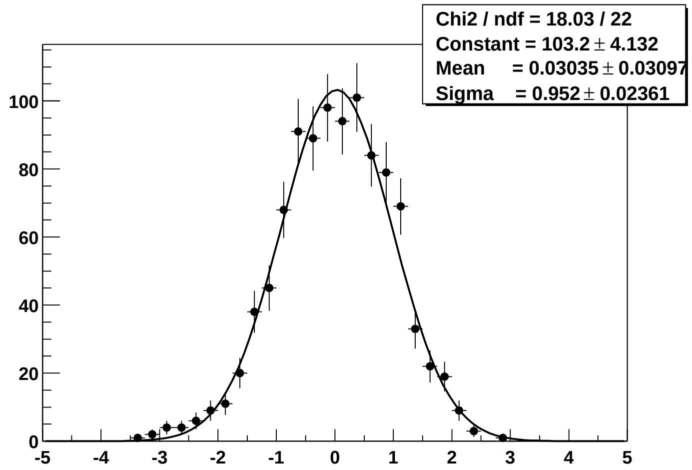
- The efficiencies of continuum and the dominant B-background modes after all cuts and best candidate selection are shown below.

Sample	Efficiency after all cuts (%)	Branching Fraction $\times 10^{-6}$	Expected number $(82\,fb^{-1})$
$K^{*\pm}\pi^0(K^{*\pm} \to K^{\pm}\pi^0)$	15.9	3.0	55
$K^{\pm}\pi^0$	4.6	12.8 ± 1.1	52.7 ± 4.6
$K^{\pm}\rho^{\mp}$	2.0	9.0 ± 1.6	16.4 ± 2.9
$K^{*\pm}(\to K^{\pm}\pi^0)\gamma$	1.1	13.4 ± 1.2	13.9 ± 1.4
$K^{*\pm}\rho^{\mp}_{Long}$	0.9	6.0 ± 6.0	5 ± 5
$\rho^{\pm}\pi^0$	0.4	11.0 ± 2.7	3.6 ± 0.9
$\rho^{\pm}K^{*0}_{Long}$	0.3	12 ± 12	3.2 ± 3.2
$K^{*\pm}(1430)\pi^0$	-	-	2.75 ± 2.75
$\pi^0 K^{*0}(\to K^{\pm}\pi^{\mp})$	4.9	0.4 ± 1.9	1.8 ± 8.2
generic $b \to c$	5.2×10^{-5}	-	93.0 ± 6.8
u,d,s,c,τ	3.3×10^{-2}	-	8500

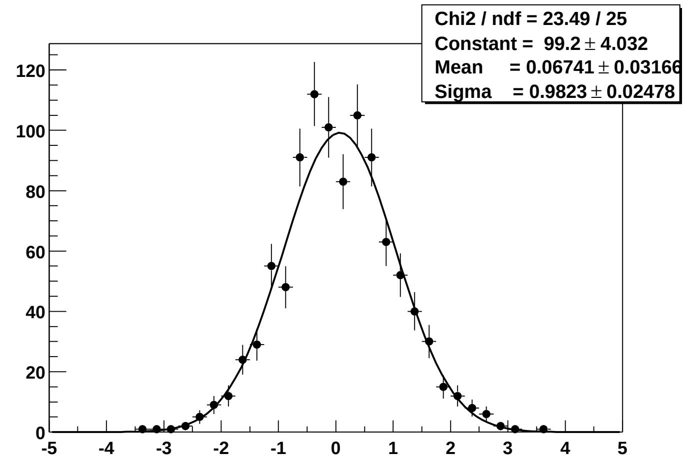
Fit Validation - “Toy Studies”

- To test the validity of our total likelihood PDF,we perform 1000 toy studies on PDF generated data sets and fit to them. We hope to get back what we put in, the systematic difference is called the pull. This study is then repeated with randomly sampled MC data (’Boot Strapped’) to get a handle on correlations and biases.
- Extensive tests reveal pulls are centered on zero, widths are ~ 1. No systematic correction needed for PDF .

Pull on total signal yield.



Pull on signal asymmetry.

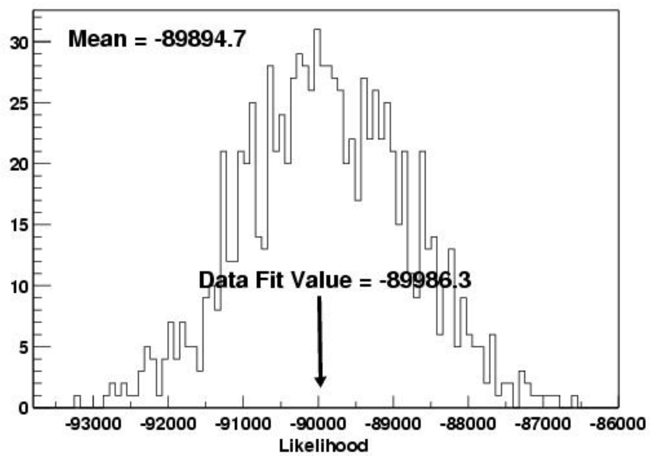


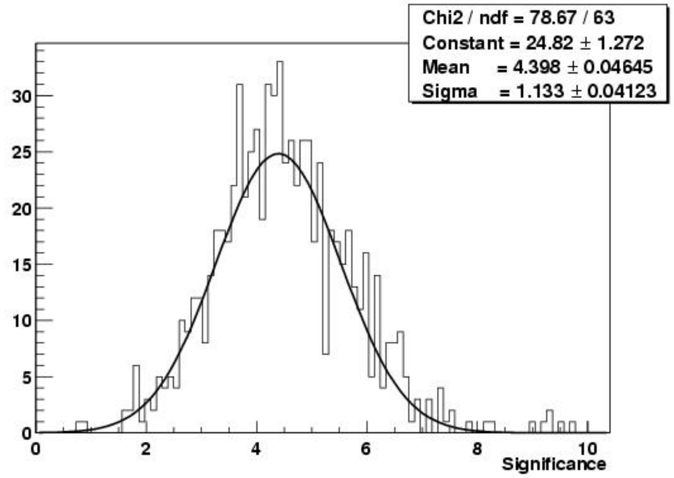
Summary of Systematic Errors

Absolute Systematic Errors on Yields	
Background Normalisation	$^{+4.0}_{-4.1}$
Pdf Shapes	$^{+3.0}_{-2.6}$
SCF fraction	± 2.45
Total	$^{+5.6}_{-5.4}$
Relative Errors on BF	
Efficiency Estimation	$\pm 10.6\%$
B Counting	± 1.6
Total	$\pm 10.7\%$
Systematic Errors on Asymmetries	
Background Asymmetry	$^{+0.059}_{-0.075}$
Detector Asymmetry	± 0.003
Total	$^{+0.059}_{-0.075}$

Blind Fits to Data

- Blind fit results to data are used to produce toys.
  - NLL value is consistent with expectation from toys.
  - Expected significance is $\sim$ 4.4, where significance is defined as $\sqrt{-2\log(\mathcal{L}_{\mathrm{Null}}/\mathcal{L}_{\mathrm{Max}})}$

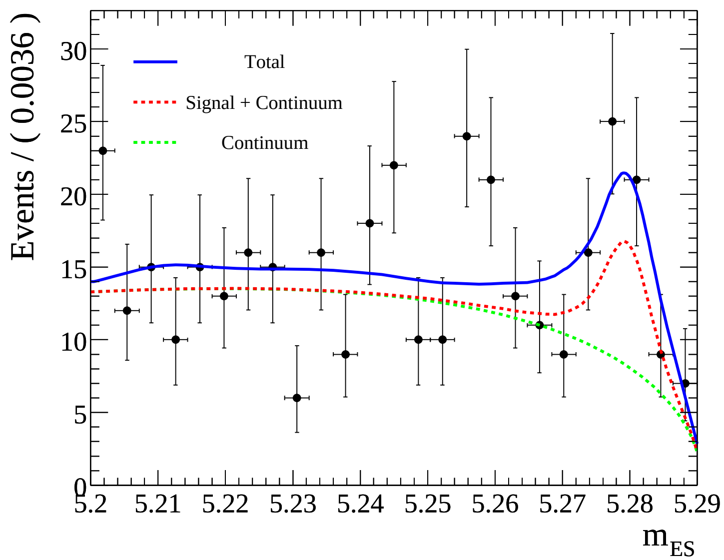




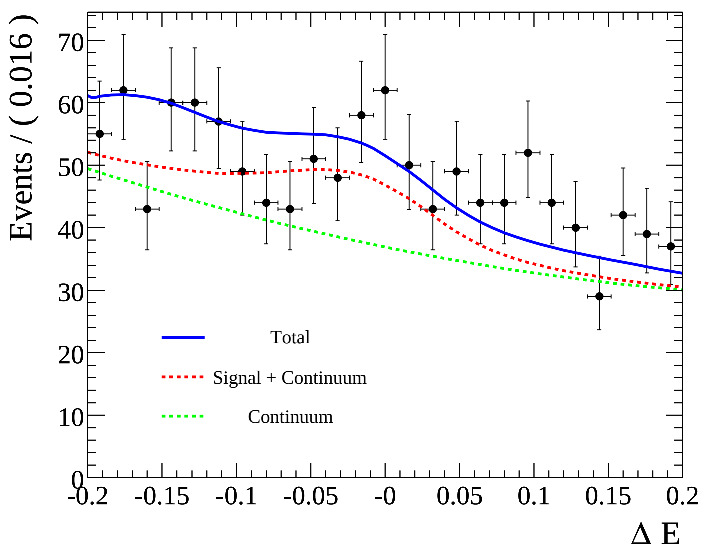
Current Status and Outlook.

- Systematics dealt with.
- Analysis looks healthy.
- Evidence of observation.
- Possibly open up Dalitz plot for higher modes. Non-trivial!

m_{ES} likelihood projection.

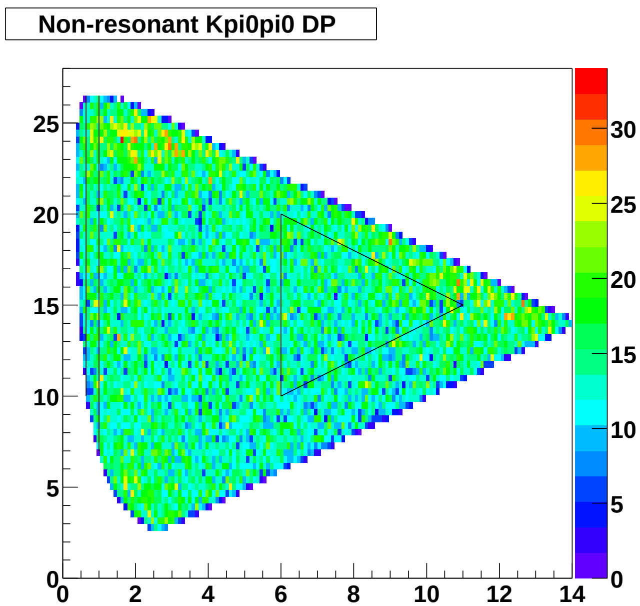


ΔE likelihood projection.



Estimation of Non-resonant pollution.

- Non-resonant $B^{\pm} \to K^{\pm}\pi^0\pi^0$ branching fraction/asymmetry unmeasured.
- Possible contamination, looks identical to resonant signal in likelihood fit variables.
- Cut a section (triangle shown) in Dalitz plot far from signal and possible higher resonance bands.
- Form PDFs exactly analogous way to the signal analysis in this region for all modes.



- Use MC ratio $R = N_{\mathrm{K^{*}band}} : N_{\mathrm{NR\ area}}$ and fitted number of non-resonant from data to estimate non-resonant population in signal region.
- Not a non-resonant branching fraction measurement - dalitz efficiency variations swallowed up in ratio. Region A not optimised, low statistics expected.

Higher K^{**} pollution.

- Higher K^{**} modes not measured.
- Beyond scope of this analysis to try and measure them.
- Potential problems if they leak into signal band: imitate signal, possible interference.
- Many: $K^*(1410)$ $K_0^*(1430)$ $K_2^*(1430)$ $K^*(1680)$.

- Be conservative! $K_0^*(1430)$ has the broadest tail. Fit for higher K^* s in side-band and extrapolate back using Breit-Wigner lineshape. Lineshape in reality is more complicated and interference possible. For systematics, assign 100% error.
- After careful analysis, expect 2.75 events in signal region.