$B^- \rightarrow D^0 K^{*-}$ and the CKM angle γ at BABAR

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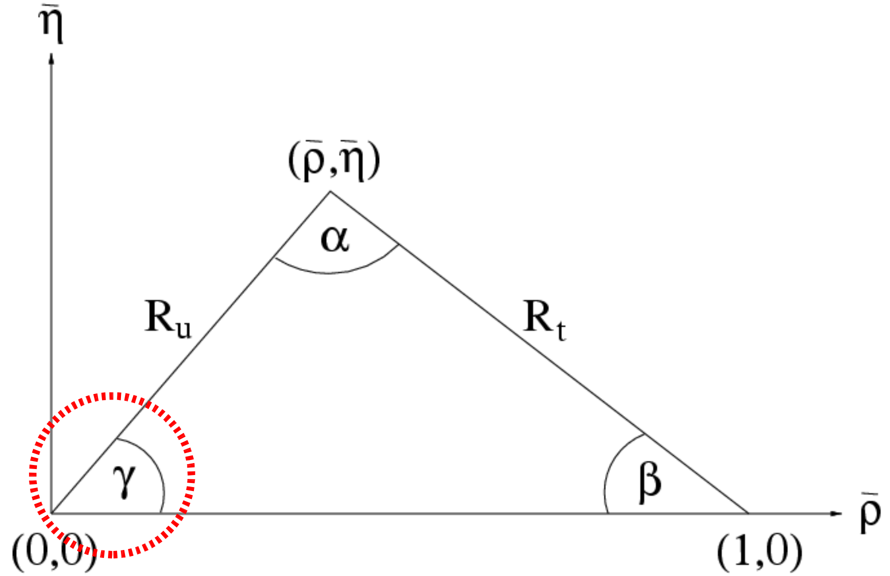
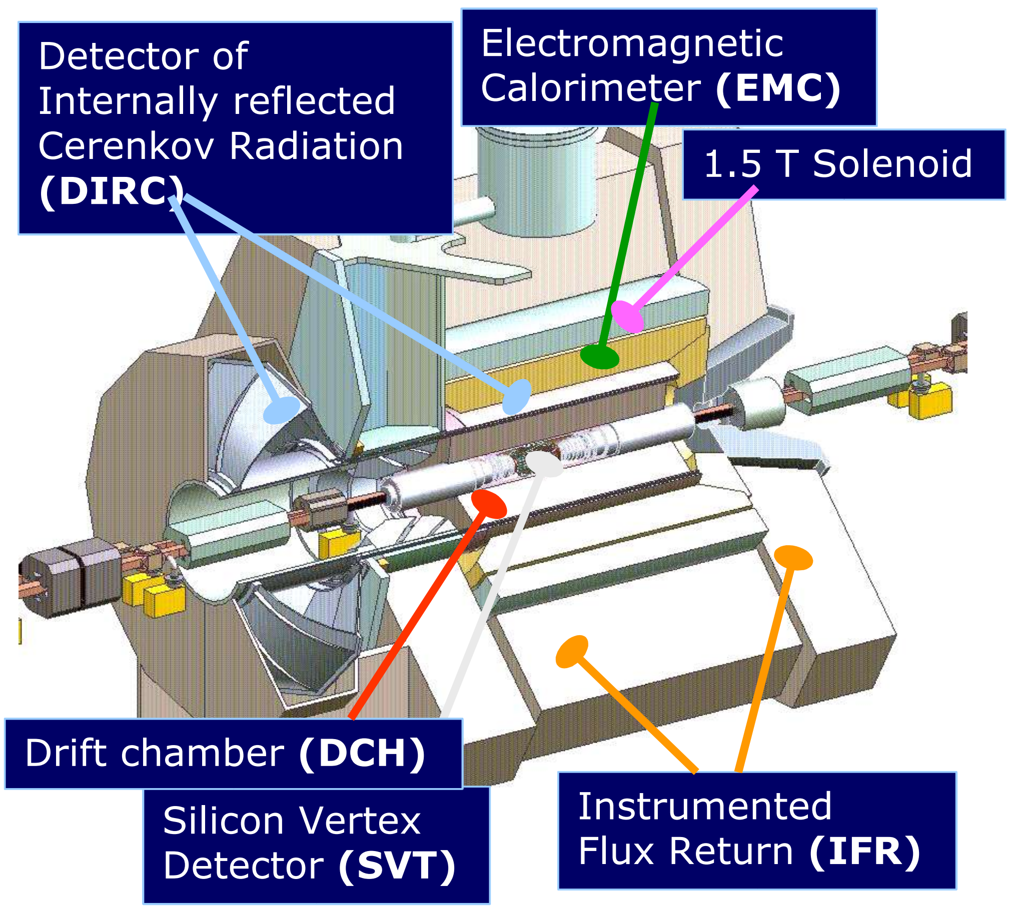


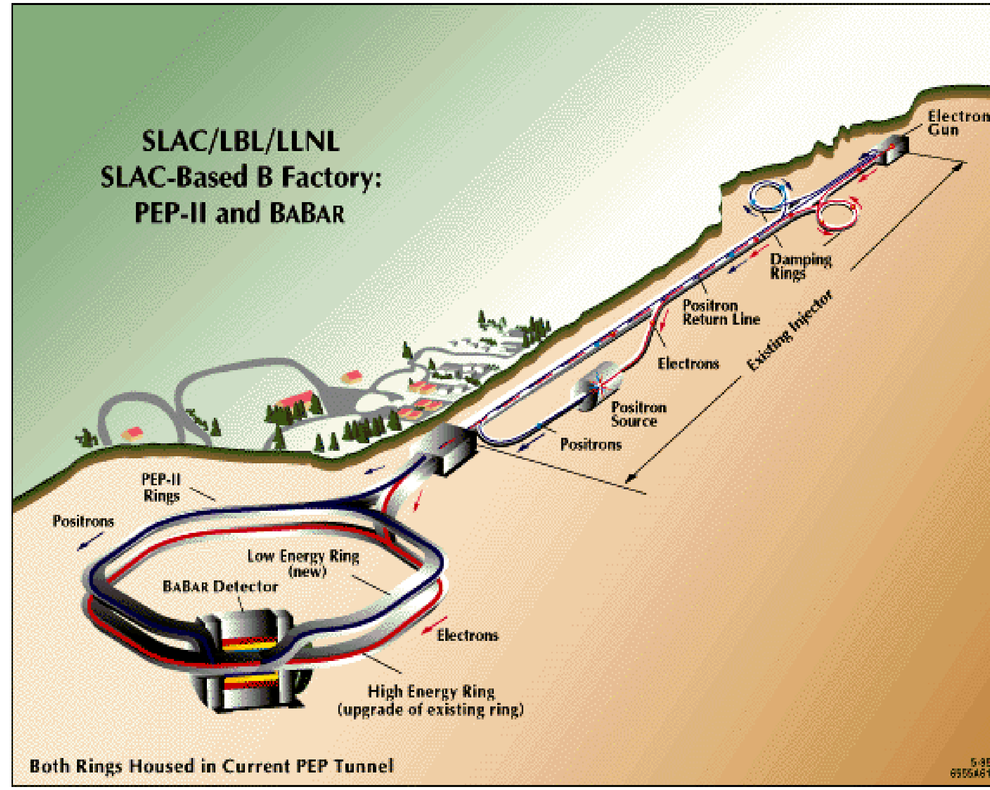
Introduction

- BaBar
- The CKM matrix and unitarity triangle
- Extracting γ with the GLW method
- Event selection
- Fit motivation
- The future of the measurement

The BaBar Detector

- Situated on the PEP-II storage ring at SLAC
- $e^+ e^-$ colliding B-factory

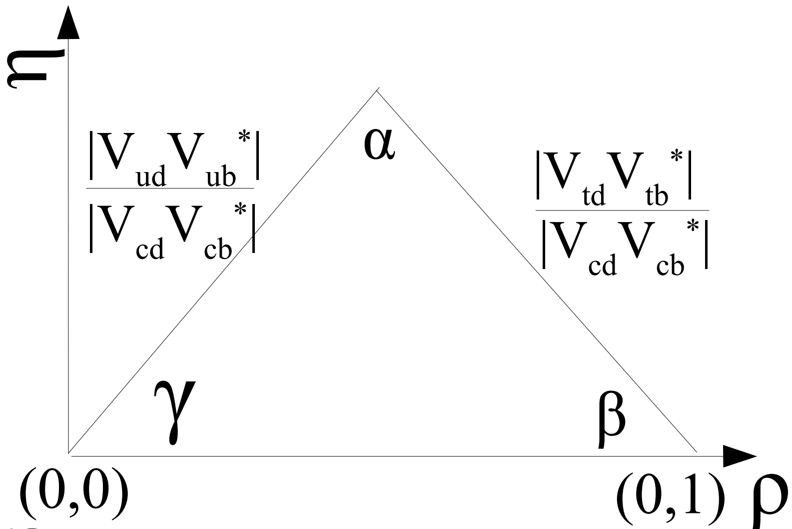




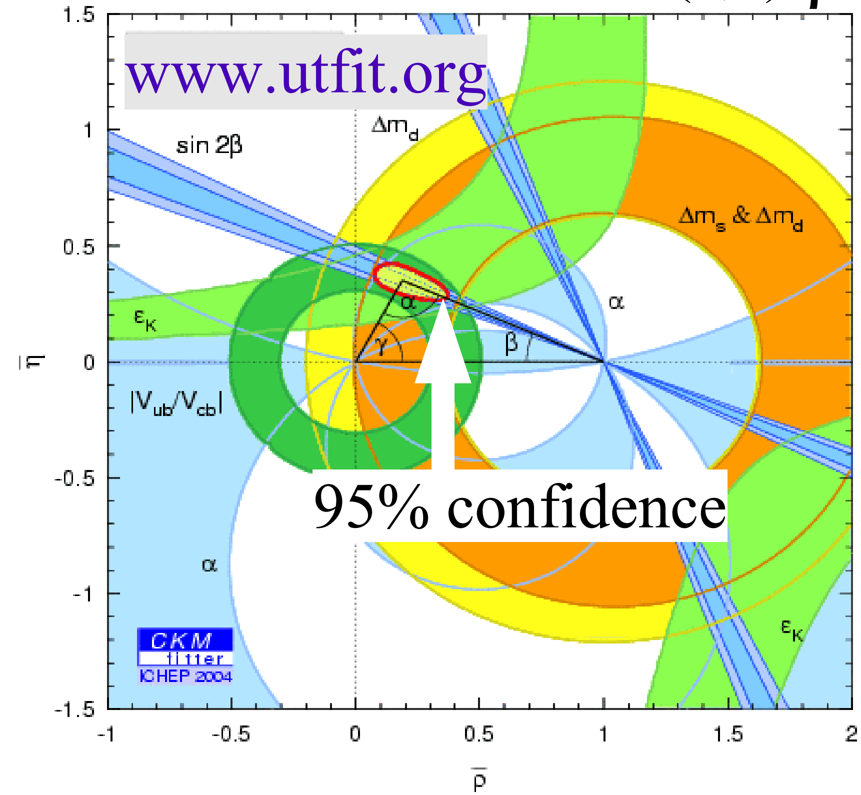
- Asymmetric beam energies
  - 9 GeV e^-
  - 3.1 GeV e^+
- 210 fb^{-1} on peak data to date

The CKM Triangle and γ

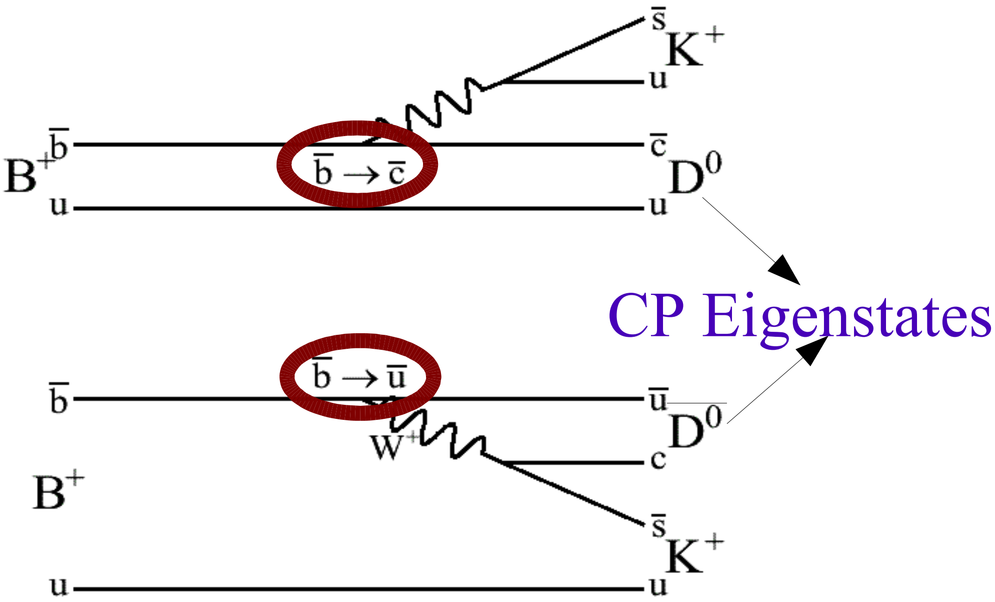
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



- 6 Unitarity triangles can be drawn.
  - "The" Unitarity triangle has sides of comparable length.
- $V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$
- $\gamma = \mathrm{Arg}(-V_{ub}V_{cb}^{*}/V_{cd}V_{cb}^{*})$
- Current estimate from global fit to $|V_{UB}|/|V_{CB}|$, ε_K, Δm_d, Δm_s and $\sin(2\beta)$,
  - $\gamma = 57 \pm 9^{o}$



The GLW method to extract γ



- Method valid for D(*)K(*)$^-$ decays of the B.
- Asymmetry arises from interference of D^0 / D^0bar decays.
- 3 measurables ($A_\pm$, R_+, R_-) and 3 unknowns (r_B,δ,γ).

$$\mathcal{A}_\pm = \frac{\Gamma(B^- \to D^0_{CP\pm}K^{*-}) - \Gamma(B^+ \to D^0_{CP\pm}K^{*+})}{\Gamma(B^- \to D^0_{CP\pm}K^{*-}) + \Gamma(B^+ \to D^0_{CP\pm}K^{*+})} = \frac{\pm 2 r_B \sin\delta \sin\gamma}{1 \pm 2 r_B \cos\delta \cos\gamma + r_B^2}$$

$$\mathcal{R}_\pm = \frac{\Gamma(B^- \to D^0_{CP\pm}K^{*-}) + \Gamma(B^+ \to D^0_{CP\pm}K^{*+})}{\Gamma(B^- \to D^0 K^{*-})} = 1 \pm 2 r_B \cos\delta \cos\gamma + r_B^2$$

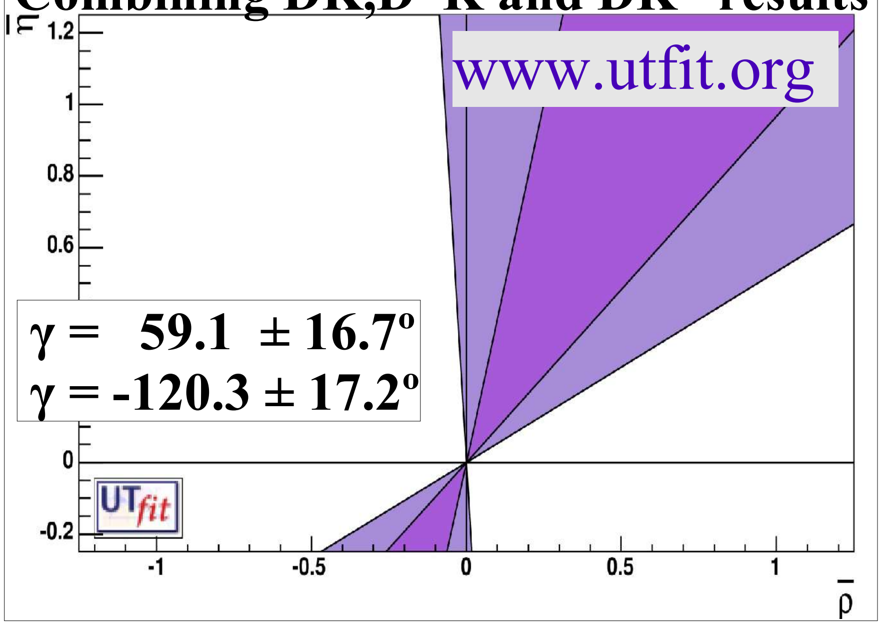
$$r_B = \frac{|A(b \to u)|}{|A(b \to c)|} = 0.1 \to 0.3$$

- But: small branching fractions.
- CP odd = $K_s\pi$, $K_s\varphi$, $K_s\omega$. (~10^{-6})
- CP even = KK, ππ. (~10^{-7})
- Non CP = Kπ, $K\pi\pi^0$, Kπππ (~10^{-5})

Current Standing

- BABAR ($D^0 \to K_s\pi$, $K_s\phi$, $K_s\omega$, KK, ππ, Kπ, $K\pi\pi^0$, K3π) ($K^* \to K_s\pi$) $205 fb^{-1}$
  - $\mathcal{A}_{CP+} = -0.09 \pm 0.20(stat.) \pm 0.06(syst.)$
  - $\mathcal{A}_{CP-} = -0.33 \pm 0.34(stat.) \pm 0.10(syst.)\ (+1.15 \pm 0.12) \cdot (\mathcal{A}_{CP-} - \mathcal{A}_{CP+})$
    $\mathcal{R}_{CP+} = +1.77 \pm 0.37(stat.) \pm 0.12(syst.)$
  - $\mathcal{R}_{CP-} = +0.76 \pm 0.29(stat.) \pm 0.06(syst.)\ {}^{-\,0.04}_{-\,0.14}$
  - The 3rd Error term accounts for possible interference in the final states of φ and ω resonances.
- Belle ($D^0 \to K_s\pi$, $K_s\phi$, $K_s\omega$, KK, ππ, Kπ, $K\pi\pi^0$, K3π) ($K^* \to K_s\pi$) $95 fb^{-1}$
  - $A_+ = -0.02 \pm 0.33(stat) \pm 0.07(sys)$
  - $A_- = -0.19 \pm 0.50(stat) \pm 0.04(sys)$
- Both measurements are dominated by statistics!
- **Increase** stats with the **$K^*(K\pi^0)$** decay.

Combining DK,D*K and DK* results



Selection Variables

For $B^- \rightarrow D^0 K^{*-}(K\pi^0)$

Key: Continuum rejection, fake D^0 rejection, selection refinement, signal region.

- Fisher discriminant
  - composed of several event shape variables.
- The invariant mass of K*, D^0, π^0, ω.
- $\cos(\theta_{Helicity})$ on K* and D^0
  - The "decay angle"
  - The angle between the granddaughter in the daughter's rest frame, and the daughter in the mother's rest frame.
- Particle Identification (PID) on Kaons and Pions.

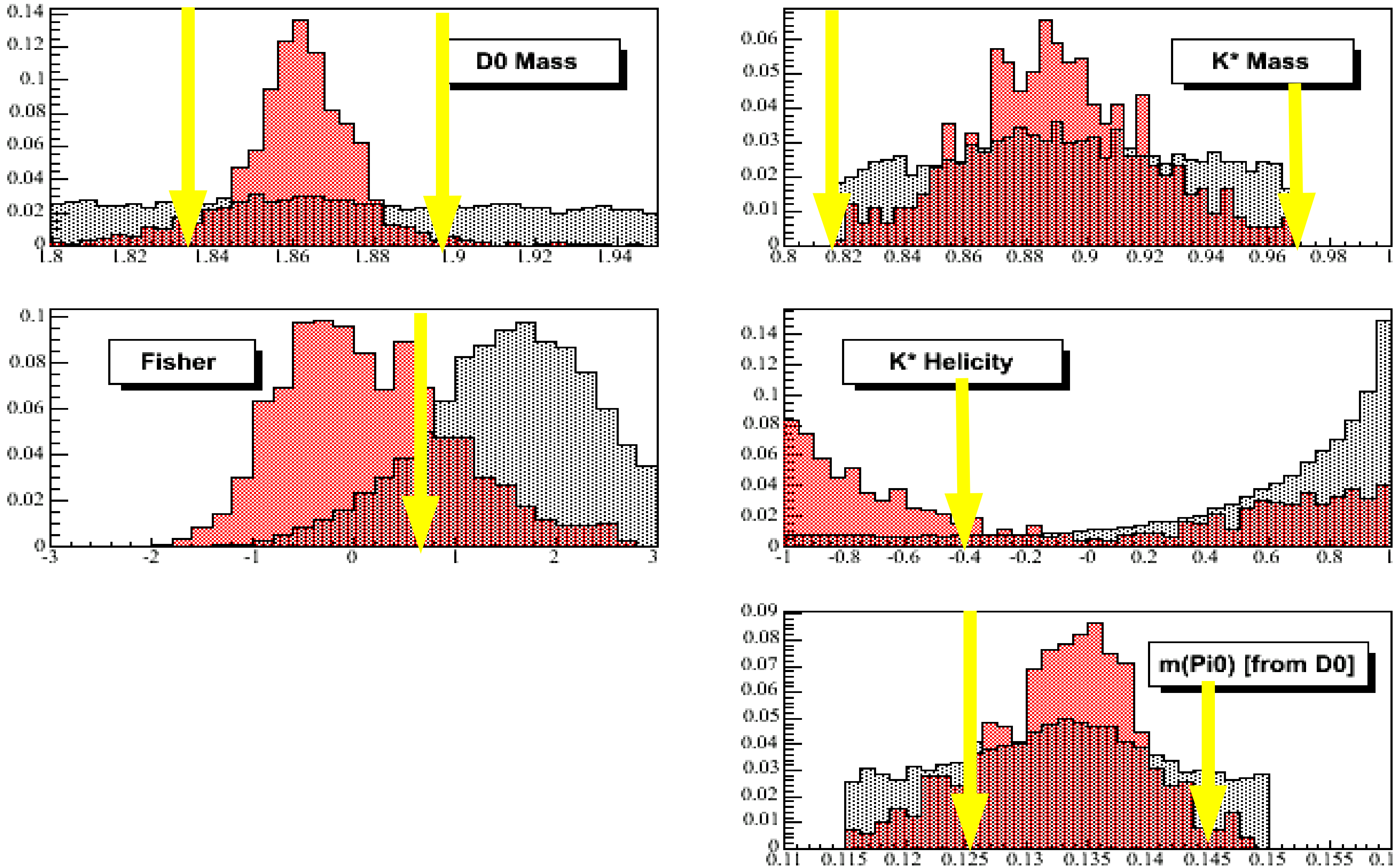
- $m_{ES} = (E^{*2}_{BEAM} - p^{*2})^{1/2}$
- $\Delta E = E^*_{\Upsilon(4s)} - E^*_{BEAM}$

Where p* = B momentum in Υ(4s) centre-of-mass frame.

- **Note:**
  - Cuts are optimised on **MC** to maximise **Signal/(Signal+Background)$^{1/2}$**.
  - Cuts are **Aligned with $K^*(K_s\pi)$** decay modes.
  - **Blind** analysis.

Discriminating Variables Used ($K\pi\pi^0$)

Signal vs **Background** (MC) scaled to unit area.



Efficiency Figures

- 3σ slice in ΔE (75 MeV).
- Fitted in m_{ES} and integrated 5.27-5.29 GeV.

	Eff (%)	$K\pi^0$ Events in $200 fb^{-1}$(MC)	
$K\pi$	5.0 ± 0.1	69 ± 1.5	
$K\pi\pi^0$	2.2 ± 0.1	105 ± 3.7	
$K3\pi$	2.8 ± 0.1	74 ± 2.6	$K^*(K_s\pi)$ $205 fb^{-1}$ (ICHEP04-Data)
	Total	248 ± 4.8	498 ± 29
KK	4.4 ± 0.1	8.6 ± 0.2	
$\pi\pi$	4.1 ± 0.1	2.9 ± 0.1	$K^*(K_s\pi)$ $205 fb^{-1}$ (ICHEP04-Data)
	Total	11.5 ± 0.1	15.1* ± 5.8
$K_s\pi$	0.9 ± 05	8.2 ± 0 .4	
$K_s\varphi$	2.2 ± 08	1.7 ± 0.1	
$K_s\omega$	0.8 ± 05	2.3 ± 0.2	$K^*(K_s\pi)$ $205 fb^{-1}$ (ICHEP04-Data)
	Total	12.2 ± 0.5	34.4 ± 6.9

- Sample is then split on charge!
- Addition to $K^*(K_s\pi)$ modes is hoped.

Background Numbers

- Sources of background "peaking" in m_{ES}:
  - Non-resonant ($B^- \rightarrow D^0 K^- \pi^0$) .
    - Will peak in signal region of ΔE and m_{ES}.
    - Unknown BR, Interferes with signal, introduces an additional strong phase!
    - requires special treatment.
  - Decays with similar final states which don't actually contain a D^0.
  - The other source of background is from continuum processes.
    - Well understood shape modeled in the fit.

The number of events in a 200fb^{-1} sample of generic MC

	UDS+CC	B^0	$B^\pm$ (Arg)	$B^\pm$ (Peak)	Signal	S/Sqrt(S+B)
$K\pi$	10.7 ± 2.8	0.9 ± 0.5	5.9 ± 1.6	13.7 ± 2.9	69 ± 1.5	6.9
$K\pi\pi^0$	110.5 ± 6.4	11.5 ± 1.6	26.2 ± 3.9	24.8 ± 6.4	105 ± 3.7	6.3
$K3\pi$	61 ± 5	26.2 ± 2.3	23.9 ± 3.6	14.5 ± 5.7	74 ± 2.6	5.2
KK	3.8 ± 2.7	0.7 ± 0.4	1.9 ± 1.0	3.7 ± 1.6	2.7 ± 0.1	2
$\pi\pi$	5.8 ± 2.7	0.5 ± 0.4	2.5 ± 1.1	0.0 ± 2.6	2.9 ± 0.1	0.7
$K_s\pi^0$	2.3. ± 1.3	0.5 ± 0.3	3.4 ± 1.6	1.2 ± 1.2	8.2 ± 0 .4	2.2
$K_s\varphi$	1.2 ± 0.5	0.4 ± 0.4	0.0 ± 2.2	3.3 ± 1.7	1.7 ± 0.1	0.7
$K_s\omega$	14.2 ± 3.8	7.8 ± 1.9	12.0 ± 2.8	1.0 ± 2.1	2.3 ± 0.2	0.4

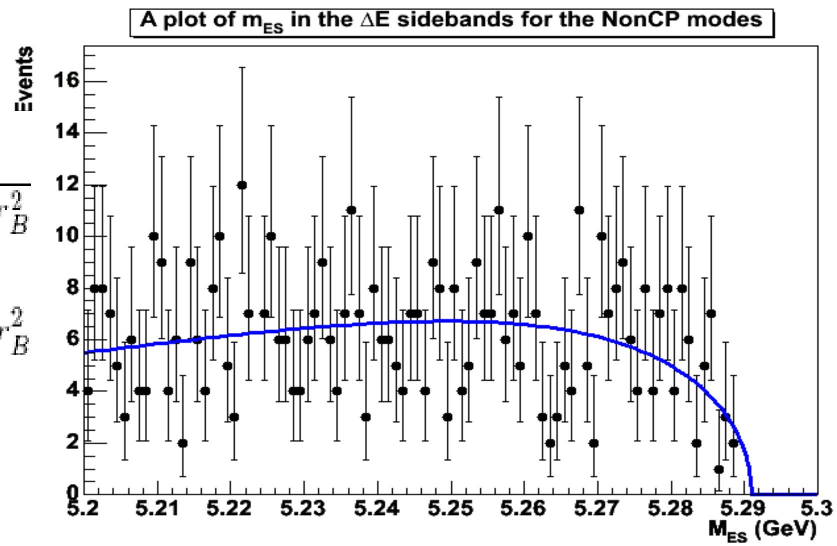
- $K_s\pi$ and KK modes provide the statistical power.

Fit Strategy

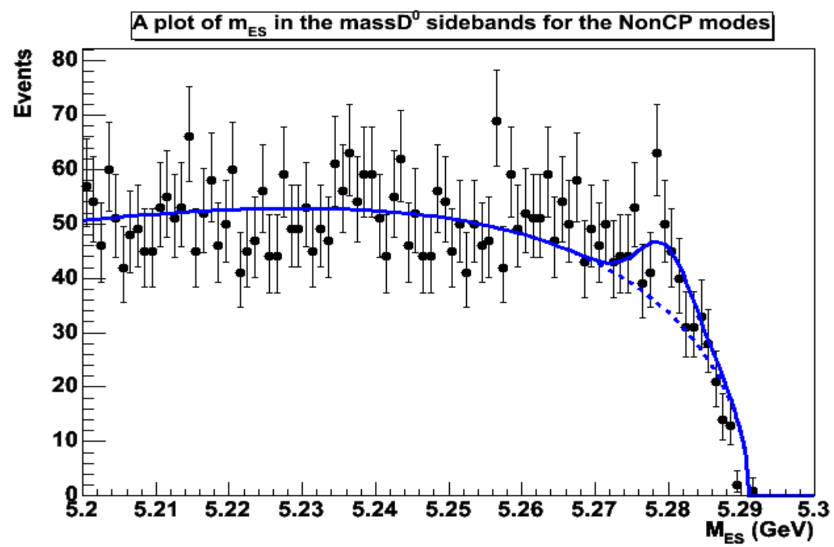
- Trying to extract $A_{\pm}$ and $R_{\pm}$

$$\mathcal{A}_{\pm} = \frac{\Gamma(B^- \to D^0_{CP\pm}K^{*-}) - \Gamma(B^+ \to D^0_{CP\pm}K^{*+})}{\Gamma(B^- \to D^0_{CP\pm}K^{*-}) + \Gamma(B^+ \to D^0_{CP\pm}K^{*+})} = \frac{\pm 2 r_B \sin\delta \sin\gamma}{1 \pm 2 r_B \cos\delta\cos\gamma + r_B^2}$$

$$\mathcal{R}_{\pm} = \frac{\Gamma(B^- \to D^0_{CP\pm}K^{*-}) + \Gamma(B^+ \to D^0_{CP\pm}K^{*+})}{\Gamma(B^- \to D^0 K^{*-})} = 1 \pm 2 r_B \cos\delta\cos\gamma + r_B^2$$



- Overview: Fit m_{ES} in (Data)
  - Sidebands of ΔE to fix Argus parameter.
  - Sidebands of the D^0 mass to get peaking background.
- Split dataset based on charge.
  - Fit N_+ N_-



The Future

- Fit studies to date show that statistics are too low
- Intention is to include with the $K^*(K_s\pi)$ events.
  - Non-res phase under study.
  - Hopefully assign a systematic.
- My thesis will present a combined fit.

Conclusions

- Direct measurement of γ is important!
- Statistics starved.
  - Best measurements to date limited by stats.
  - These modes lack statistics with current dataset.
  - Combine with other K* decay to add ~40%
    - will hopefully improve overall measurement.
    - Studies ongoing.

Spare slides follow...