Charmless and Double-Charm B Decays at SLD

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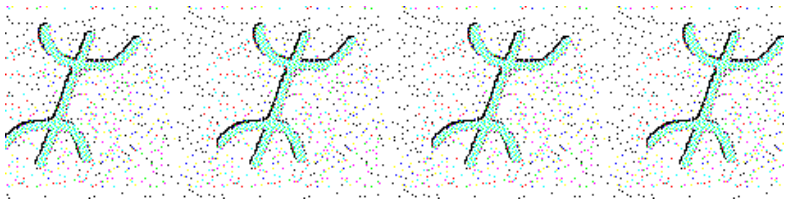
Representing the SLD Collaboration



- Measurement of $\mathcal{B}(B \to D\bar{D}X)$
- Search for exclusive charmless $B^{\pm}$ decays

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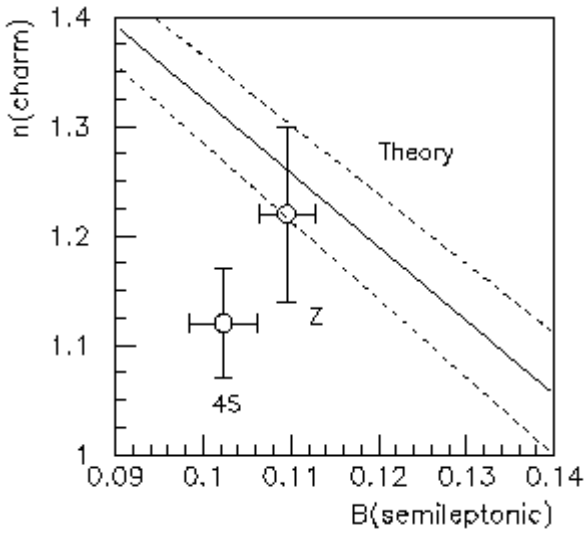
Motivation

B decay puzzle:

B semileptonic Branching Ratio (B_{SL}) and Charm Yield in B decays (n_C) appear to be too low

J. Richman, ICHEP-96



$$B_{SL} = \frac{\Gamma_{SL}}{\Gamma_{SL} + \Gamma_{Had}}$$

$$\Gamma_{Had} = \Gamma(b \to c\bar{u}d) + \Gamma(b \to c\bar{c}s) + \Gamma(b \to sg) + \Gamma(b \to u)$$

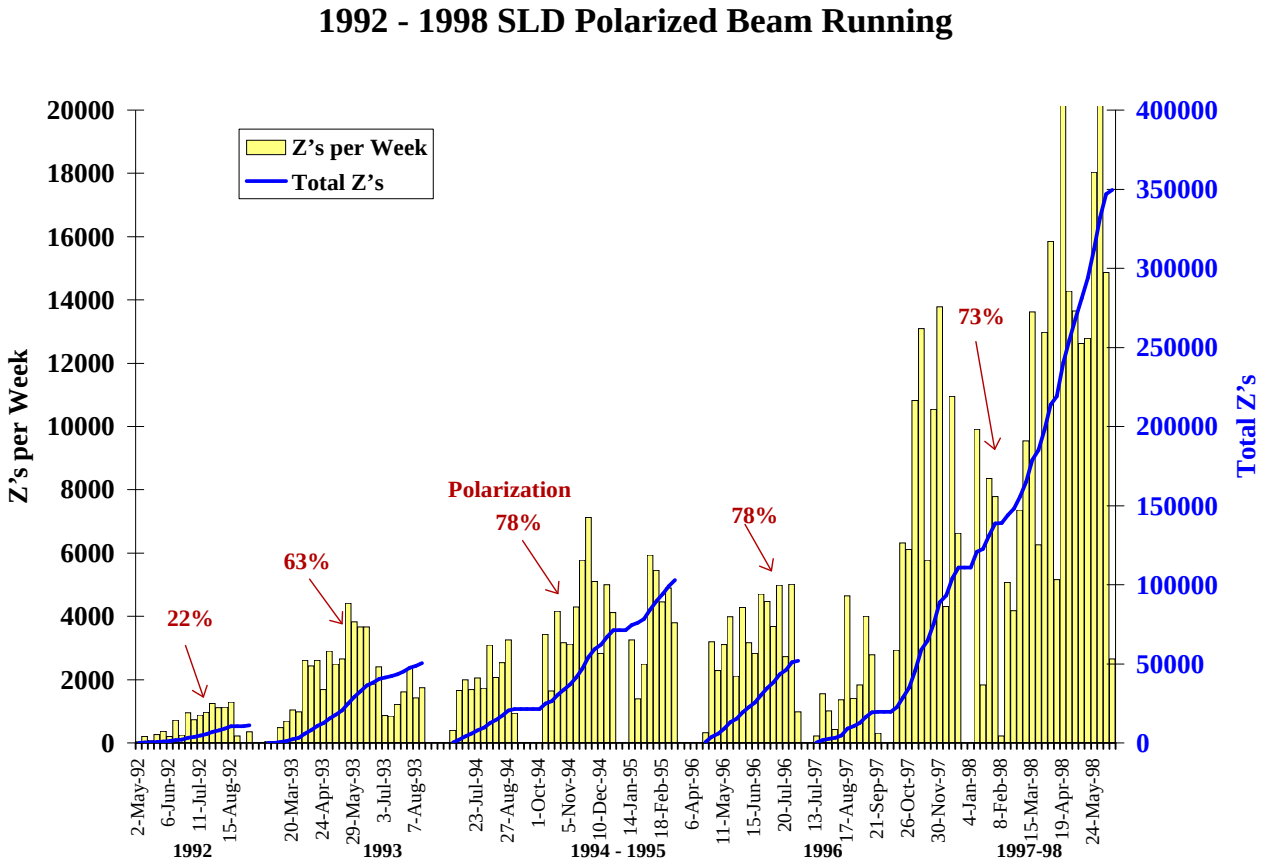
$$n_C = 1 + n_{CC} - n_{NOC}$$

- ⋆ Larger $\Gamma(b \to c\bar{c}s)$ $\Longrightarrow$ smaller B_{SL}
- ⋆ Larger n_{CC} $\Longrightarrow$ larger n_C
- ⋆ Large $\Gamma(b \to sg)$ or $\Gamma(b \to u)$ (New Physics) $\Longrightarrow$ smaller B_{SL}

e.g., A. Kagan and J. Rathsman → $\mathcal{B}(b \to sg) \sim 10\%$
See talk by A. Litke in parallel session 7

Data Sample

			$b \to c\bar{c}s$	$b \to u$
1993 – 95	$150k$ Z's	VXD2		Yes
1996 – 98	$250k$ Z's	VXD3	Yes	Yes
Spring 98	$150k$ Z's			Yes



SLD Detector

- **Precise 3D CCD pixel vertex detector**

  Topological vertexing

  B mass tag $\Longrightarrow$ $\epsilon = 50\%$, $\pi = 98\%$

  B decay length resolution ~ 100 μm

- **Electron beam polarization**

  Very good $b - \bar{b}$ separation

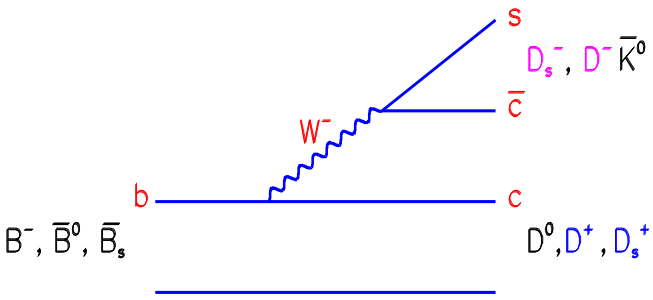
- **Čerenkov Ring Imaging Detector**

  Good particle (Kaon) identification

Measurement of $\mathcal{B}(B \to D\bar{D}X)$

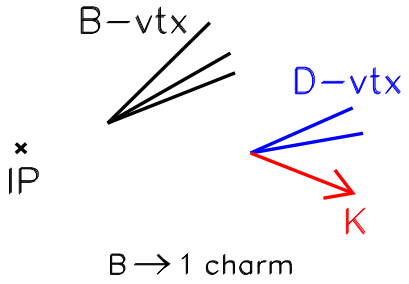
Quark transition $b \to c\bar{c}s$

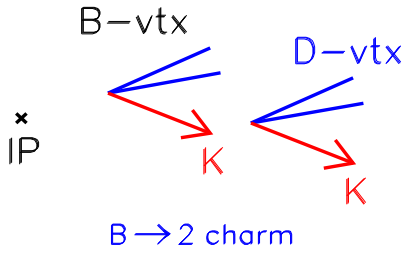
CLEO:	$\mathcal{B}(B \to D\bar{D}X)$	$= (18 \pm 4)\%$
ALEPH:		$= (25 \pm 4 \pm 4)\%$
DELPHI:		$= (17 \pm 4)\%$



At SLD:

- Select B decays with 2 separated vertices
- Require 1-vertex probability $< 5.0\%$
- Fit for $f_{D\bar{D}}$ in Data using pure $B \to$ 1-charm and $B \to$ 2-charm Monte Carlo samples
- Two techniques are utilized





1. KAON COUNTING TECHNIQUE:

Count number of (charged) Kaons in B and D vertex

Expect more $K^{\pm}$'s in D vertex for $B \to$ 1-charm

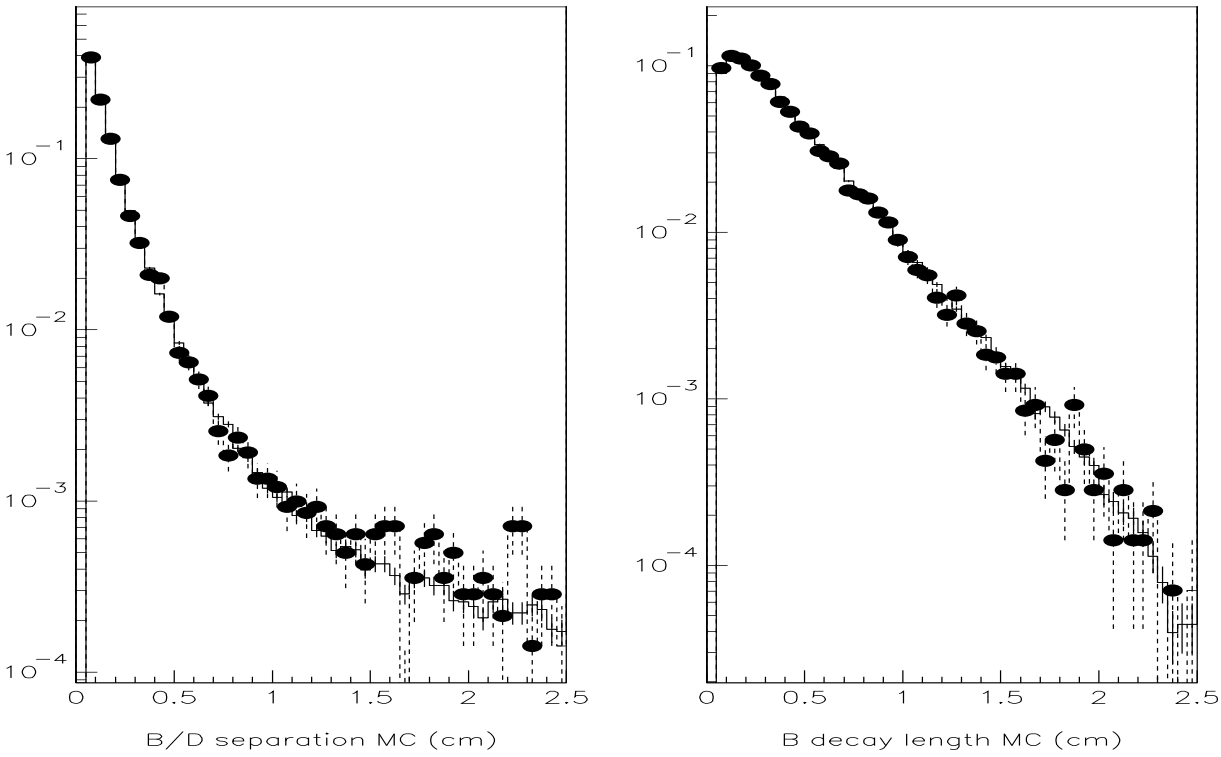
Unlike $B \to$ 2-charm, where B vertex can actually be a D

2. D CHARGE TECHNIQUE:

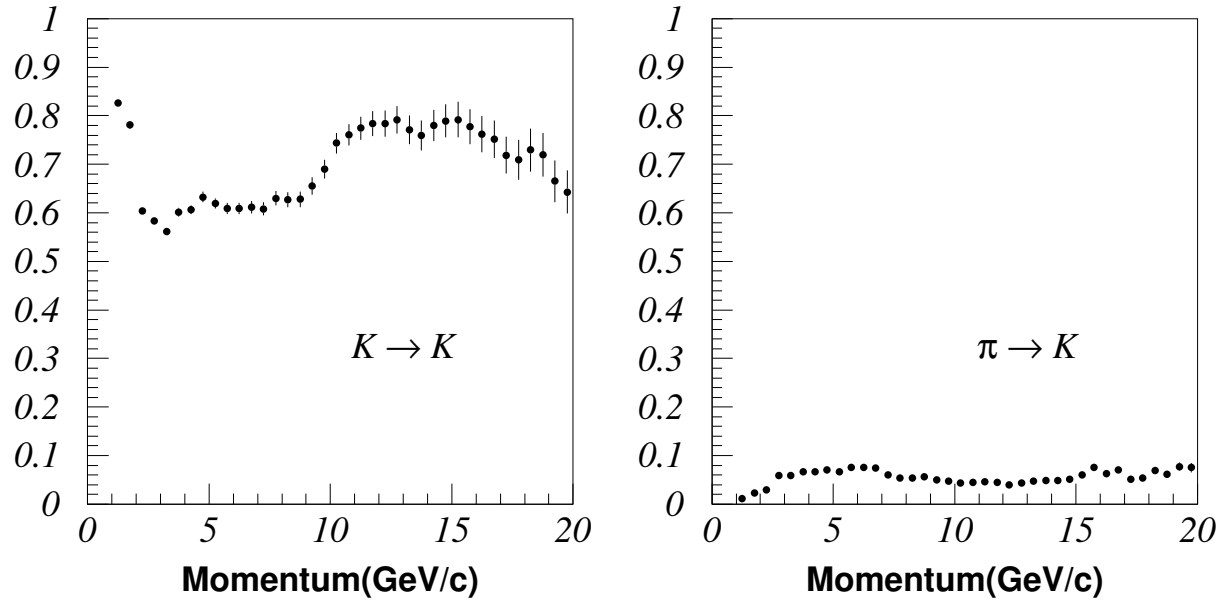
Compare charge of D vertex to flavor of B

For $B \to$ 2-charm, D vertex can have "wrong-sign" charge

D and B Decay Length



Kaon ID Efficiency



$K^{\pm}$ Counting Analysis

	$N_{K^-,B}$	$N_{K^+,B}$	$N_{K^-,D}$	$N_{K^+,D}$	$N_{K,B}/N_{K,D}$
Data	758	559	1168	746	0.688 ± 0.025
M.C. $D\bar{D}$	3115	2339	2380	1880	1.280 ± 0.026
M.C. "Not-$D\bar{D}$"	5386	3974	11489	6549	0.519 ± 0.007

$$\Longrightarrow \quad \boxed{f_{D\bar{D}} = (18.8 \pm 2.5)\%}$$

- Measured $f_{D\bar{D}}$ corrected for difference in efficiency for $B \to$ 1-charm and $B \to$ 2-charm: $\epsilon_{D\bar{D}}/\epsilon_D = 1.34 \pm 0.03$

- Track misassignment rate (between B and D vertex) calibrated using leptons

- CROSS CHECKS:

  $K^{\pm}$ Asymmetry in D Vertex
  $f_{D\bar{D}} = (29 \pm 11)\%$

  Subsamples
  $Q_V = 0$: $f_{D\bar{D}} = (20.9 \pm 4.2)\%$
  $Q_V = \pm 1$: $f_{D\bar{D}} = (17.0 \pm 3.1)\%$

Systematic Errors

Detector Systematics	σ_{stat} (abs.)
Tracking Efficiency	$\pm 0.3\%$
Tracking Resolution	$\pm 0.7\%$
$K^{\pm}$ Id. Efficiency	$< 0.1\%$
$\pi^{\pm}$ Fake Rate	$\pm 0.7\%$
Track Misassignment	$\pm 4.2\%$

Physics Systematics	
$udsc$ Background	$\pm 0.4\%$
B Multiplicity	$\pm 1.5\%$
B_s Fraction	$\pm 1.1\%$
Λ_b Fraction	$\pm 0.7\%$
$\mathcal{B}(B_{u,d} \to D^0 X)$	$\pm 0.2\%$
$\mathcal{B}(B_{u,d} \to D^+ X)$	$\pm 0.2\%$
$\mathcal{B}(B_{u,d} \to D_s^+ X)$	$\pm 0.4\%$
$B \to D\bar{D}$ Model	$\pm 1.5\%$
Charm Multiplicity	$\pm 3.2\%$
TOTAL	$\pm 5.9\%$

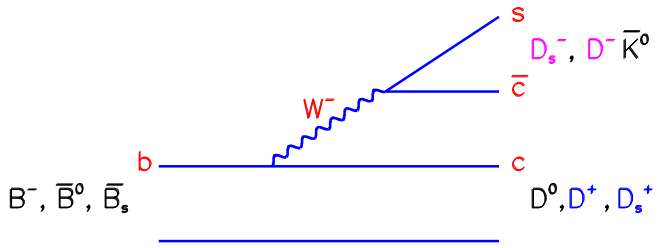
RESULT

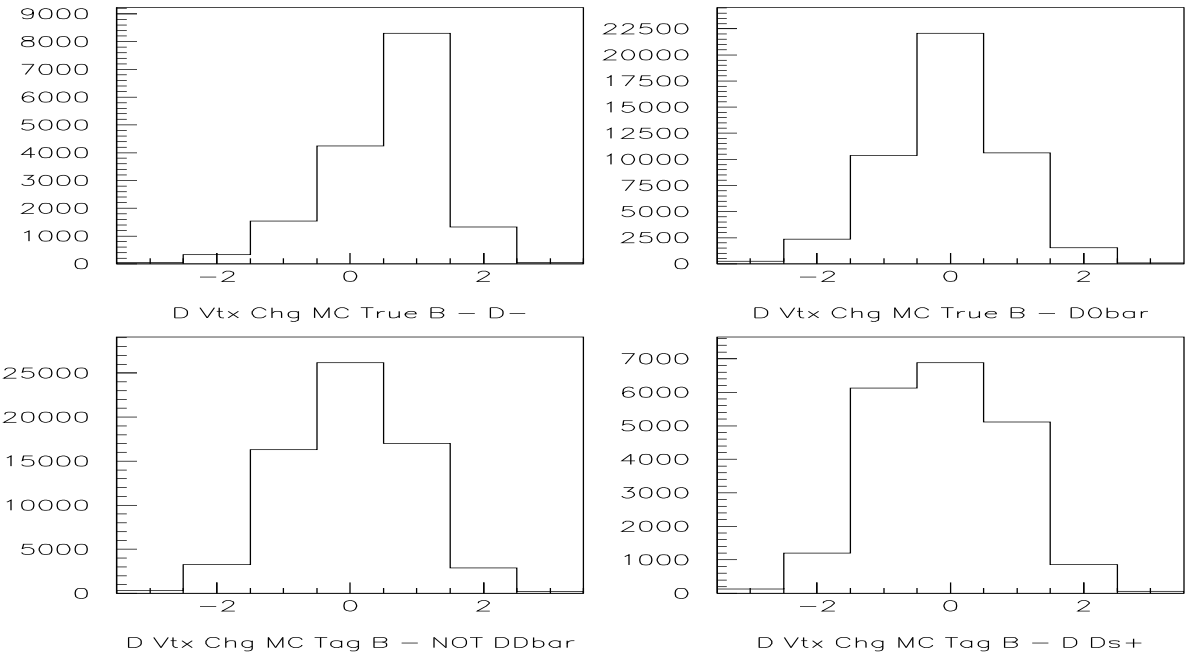
$$\mathcal{B}(B \to D\bar{D}X) = (18.8 \pm 2.5 \pm 5.9)\%$$

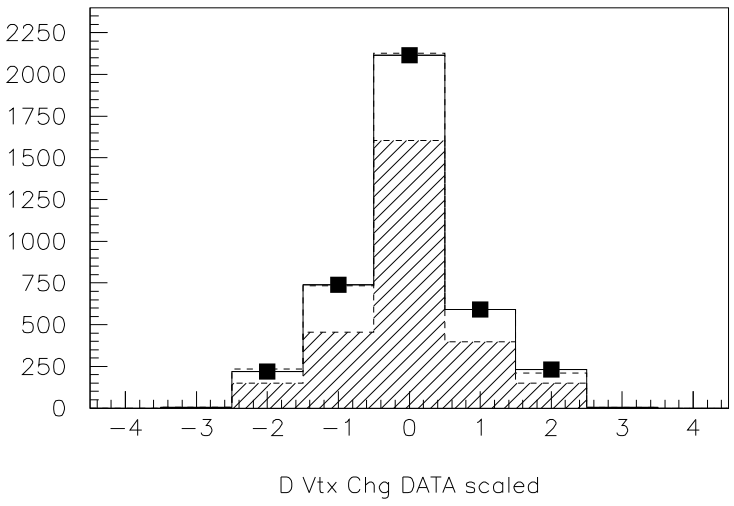
(SLD Preliminary)

D Charge Analysis

- Tag flavor of B using Polarization and Jet Charge
- For b-type B Meson:
  D Charge $= +$, if $B \to$ 1-charm
  D Charge $= +$ or $-$, if $B \to$ 2-charm
- Fit D Charge distribution in Data to Monte Carlo shapes for 1-charm and 2-charm, and extract $f_{D\bar{D}}$







- χ^2 Fit $\Longrightarrow$
  $f_{D\bar{D}} = (19.5 \pm 4.5)\%$
- Consistent with $K^{\pm}$ counting analysis

Search for Charmless B^+ Decays

- Exclusive (3-prong) hadronic channels
  $B^+ \to \rho^0 \ \pi^+(K^+)$, $\rho^0 \ \to \pi^+\pi^-$
  and $B^+ \to K^{*0}\pi^+(K^+)$, $K^{*0} \to K^+\pi^-$
- Decays due to tree-level $b \to u$ and one-loop penguin $b \to d(s)$ transitions
- Current experimental limits $\sim \times 5$ larger than theoretical predictions

	Theory	CLEO	DELPHI	ALEPH
	BR $\times 10^{-5}$	90% C.L. $\times 10^{-5}$		
$B^+ \to \rho^0\pi^+$	0.4 – 1.4	< 5.8	< 16	< 3.2
$B^+ \to \rho^0 K^+$	0.01 – 0.06	< 1.4	< 12	
$B^+ \to K^{*0}\pi^+$	0.6 – 0.9	< 3.9	< 39	

DELPHI $\longrightarrow$ $\mathcal{B}(B \to \rho(K^*)\pi) = (1.7^{+1.2}_{-0.8} \pm 0.2) \times 10^{-4}$

	Number of $\#B^+$'s	Effic. (%)	$B \to \rho\pi$ Obs	Bkg	$B \to \rho K$ Obs	Bkg	$B \to K^*\pi$ Obs	Bkg
CLEO	2.64 M	≈ 6.0	8	3.0	1	4.8	3	1.3
DELPHI	0.5 M	≈ 6.0	1	0.09	0	0.17	2	0.06

- At SLD:
  Expect relatively high efficiency, due to very good tracking and vertexing efficiency and resolution (VXD3)
- Extrapolating from DELPHI B.R. measurement, we should expect ~ 6 decays in our $550k$ Z^0 Data sample ($\sim 100k$ B^+'s)

Analysis

- **Final-State Selection**

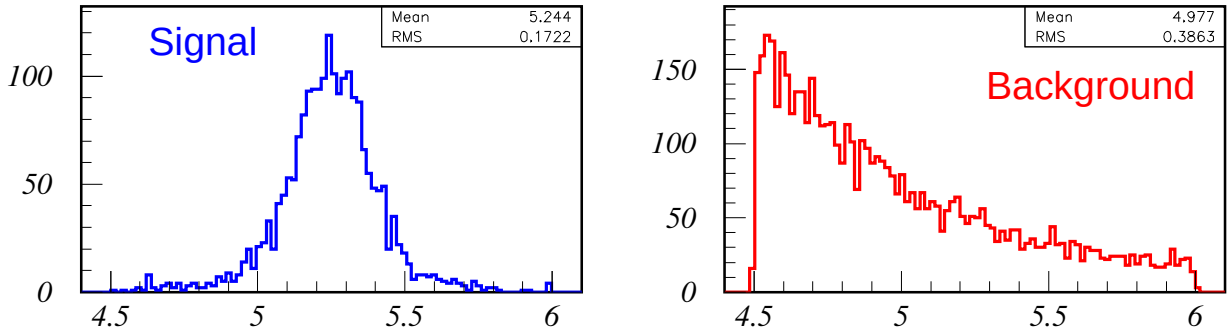
  Three-prong vertex with Charge $= \pm 1$

  Decay kinematics requirements

  B mass and energy, ρ^0 mass, K^{*0} mass, C.M. helicity angle, ...

  Track quality requirements

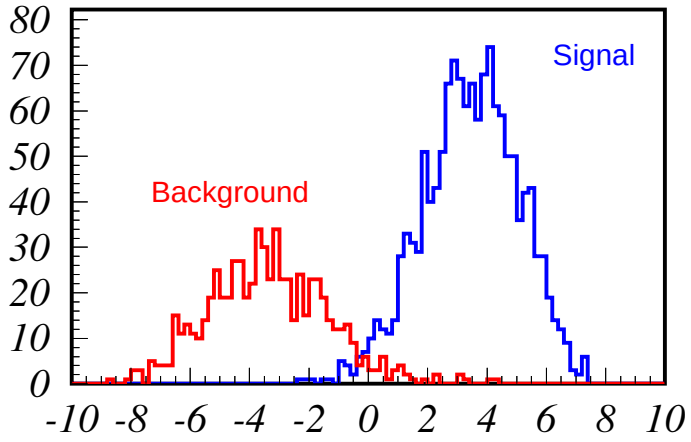
Vertex Mass



- **Fischer Discriminant Function**

  constructed using 8 kinematic variables, each with a parametrization for signal and background

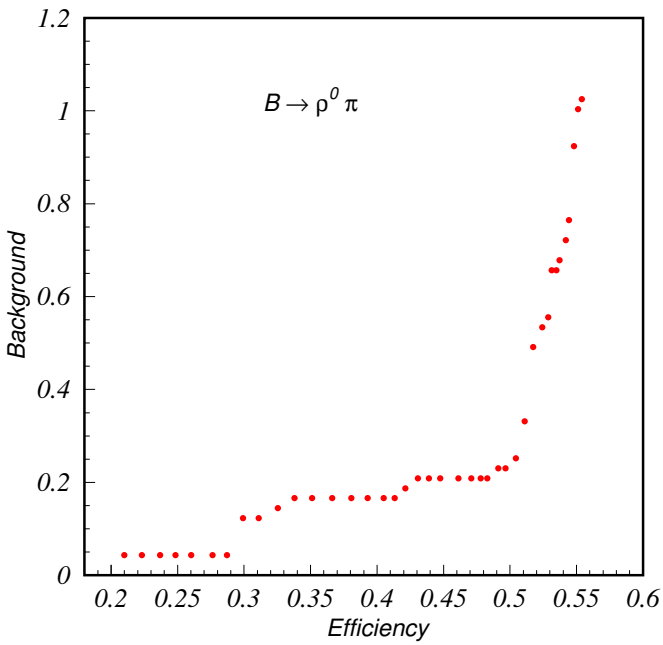
Fischer Discriminant

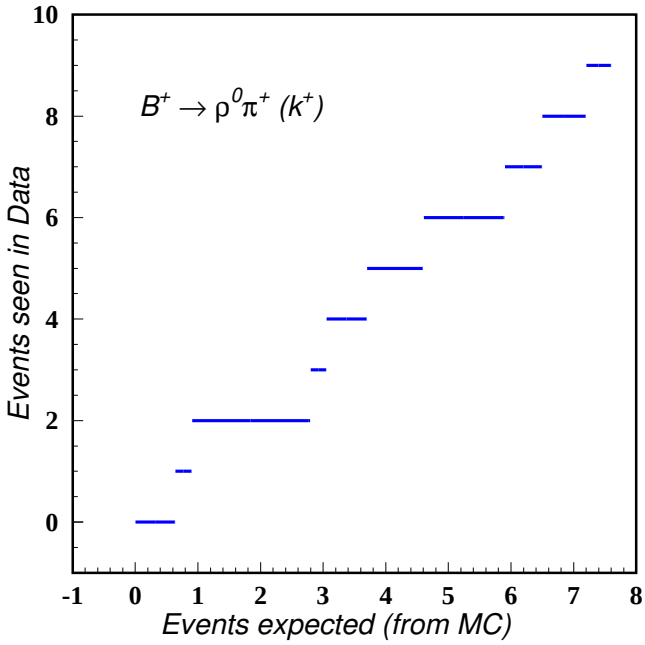


Analysis (continued)

- **Optimal Analysis Point**

  found by minimizing upper limit vs. efficiency (Poisson statistics)





- **No decays observed in Data**

	Efficiency	Decays Observed	Estimated Background
$\rho^0\pi^+$	0.50	0	0.61
$\rho^0 K^+$	0.45	0	0.61
$K^{*0}\pi^+$	0.52	0	0.37
$K^{*0}K^+$	0.46	0	0.37

- **CROSS CHECK:**

  With looser selection cuts, number of observed decays in Data tracks very well expected background from the Monte Carlo

Systematic Errors

Variation in Efficiency (%)

	$\rho^0\pi^+$	$\rho^0 K^+$	$K^{*0}\pi^+$	$K^{*0}K^+$
Mass Resolution	-0.3	-0.9	-0.4	+0.1
Tracking Efficiency	-0.6	-0.5	-0.4	-0.2
Vertex Resolution	-2.5	-1.7	-1.0	-0.9
b Fragmentation	$\pm$0.4	$\pm$0.0	$\pm$0.3	$\pm$0.4
TOTAL	3.8	3.1	2.1	1.4

RESULTS

1993 – 98 SLD Data $\longrightarrow$ 583,867 Hadronic Z^0's (101,937 $B^{\pm}$'s)

Uncertainty in $N_{B^{\pm}} = 1.1\%$

No decays seen in Data $\Longrightarrow$ 90% CL limit < 2.3 Decays

90% C.L. Upper Limit (BR $\times 10^{-5}$), including systematic errors

	CLEO	DELPHI	SLD Preliminary
$B^+ \to \rho^0\pi^+$	5.8	16	8.2
$B^+ \to \rho^0 K^+$	1.4	12	9.2
$B^+ \to K^{*0}\pi^+$	3.9	39	7.9
$B^+ \to K^{*0}K^+$			9.0

SUMMARY

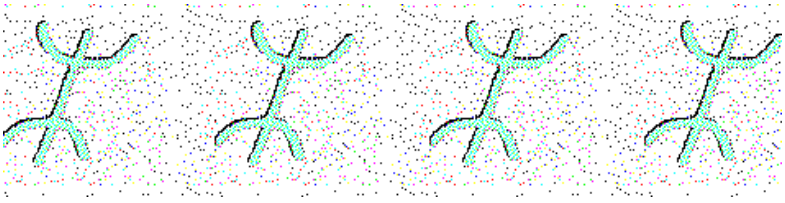
- $B \rightarrow$ Double-Charm branching ratio measurement

$$\mathcal{B}(B \rightarrow D\bar{D}X) = (18.8 \pm 2.5 \pm 5.9)\%$$

(SLD Preliminary)

$K^{\pm}$ Counting and D Charge Techniques will be combined

Will work on reducing systematic error

- Competitive upper limits on Exclusive Charmless $B^{\pm}$ Decays

- Other B Decay analyses are currently underway at SLD
  e.g., b semileptonic branching ratio