B Meson Decays to Charm

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Representing

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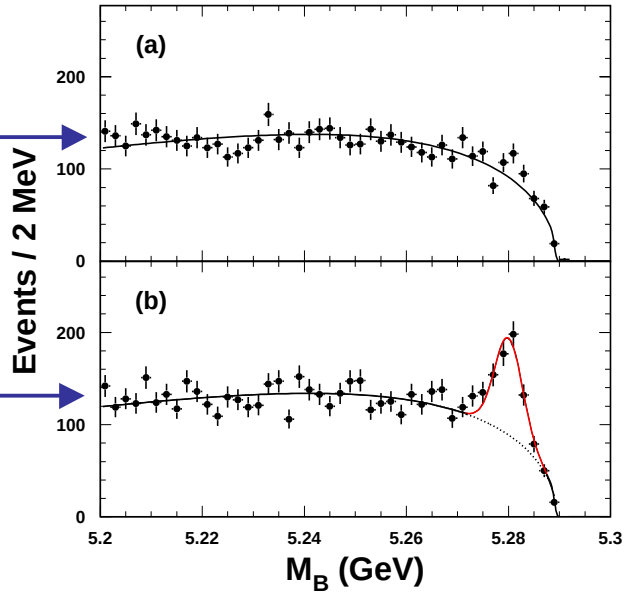
Introduction

- *Understanding hadronic B decays is crucial to insuring that decay modes used for measurement of CP violation truly reflect the underlying quark decay mechanisms expected theoretically*
- Yet only ~12% of the B decay rate into hadrons has been measured. This includes $J/\psi\ K^{(*)}$, $D^{(*)}D_s^{(*)}$ and $D^{(*)}(n\pi)^-$, $3 \geq n \geq 1$
  - Here π^-, ρ^- and a_1^- dominate (quasi-two-body)
- Since the averaged charged multiplicity in hadronic B decays is 5.8±0.1, where 2.9±0.1 comes from the $D^{(*)}$, we expect a large decay rate for 3 charged and 1 neutral pion $(4\pi)^-$

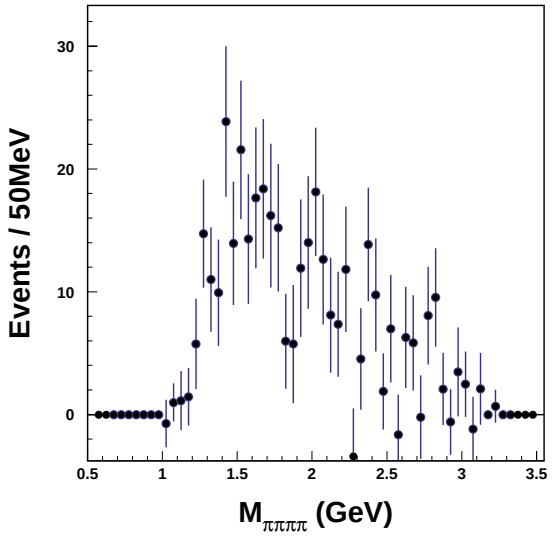
The $D^{*+}\pi^+\pi^-\pi^-\pi^o$ Final State

- (a) ΔE sidebands
  $|3.0 – 5.0\ \sigma|$
- (b) ΔE around 0 $\pm 2.0\sigma$ fit with sideband shape fixed & norm allowed to float
- Also signals in $D^o \to K^-\pi^+\ \pi^o$ and $D^o \to K^-\pi^+\ \pi^+\ \pi^-$ (not shown)
- Fit B yield in bins of $M(4\pi)$



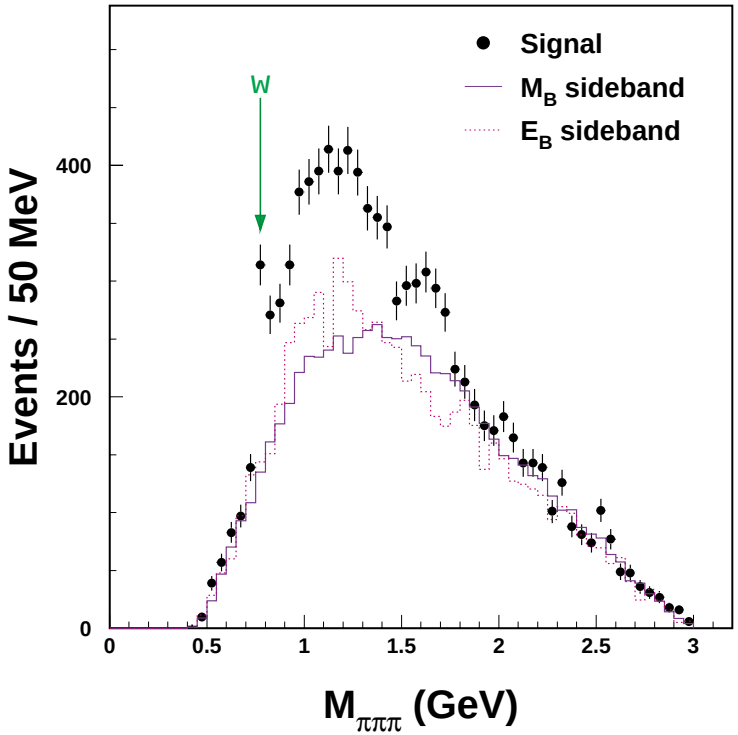
$D^o \to K^-\pi^+$

358±29

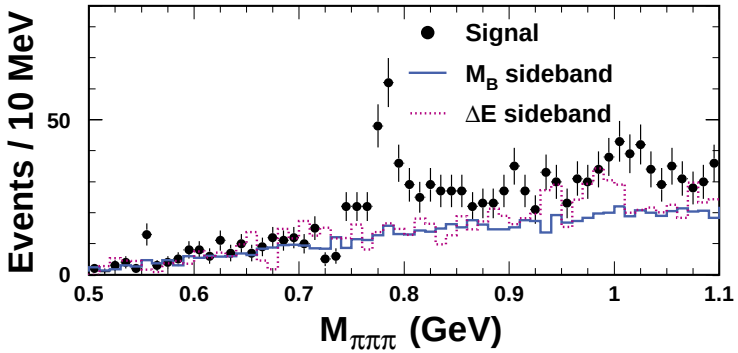


The $\pi^+\pi^-\pi^o$ Mass Distribution

- What are the decay mechanisms for the $(4\pi)^-$ final state?
- We examine the $\pi^+\pi^-\pi^o$ mass spectrum (2 combinations/event). All 3 D^o decay modes summed



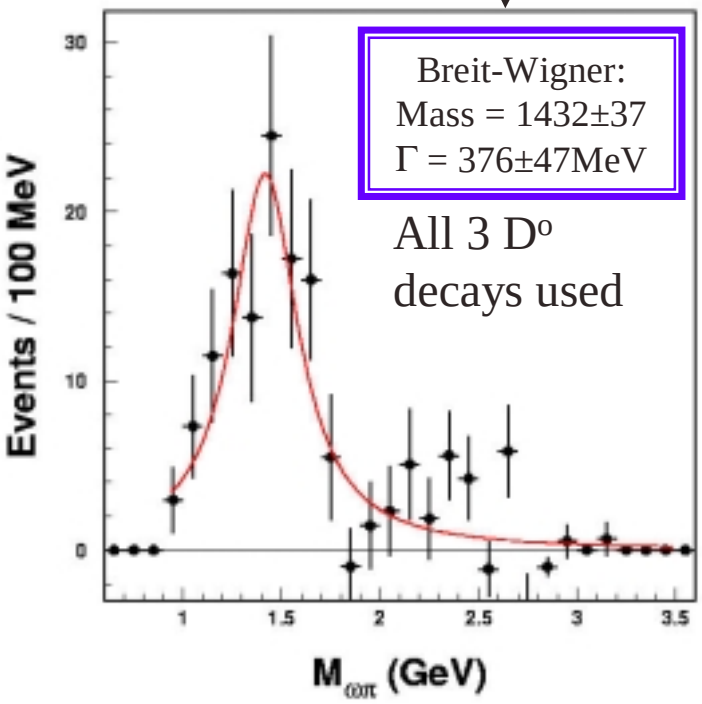
Enlarged & Dalitz plot exterior removed



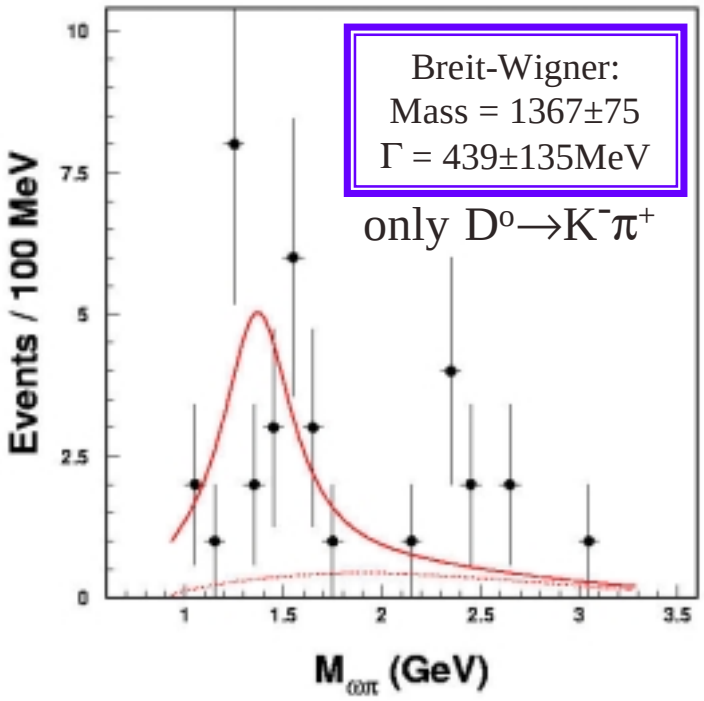
The $\omega\pi^-$ Mass Distribution

Fit M_B distribution in $\omega\pi$ mass bins

$D^{*+}\omega\pi^-$



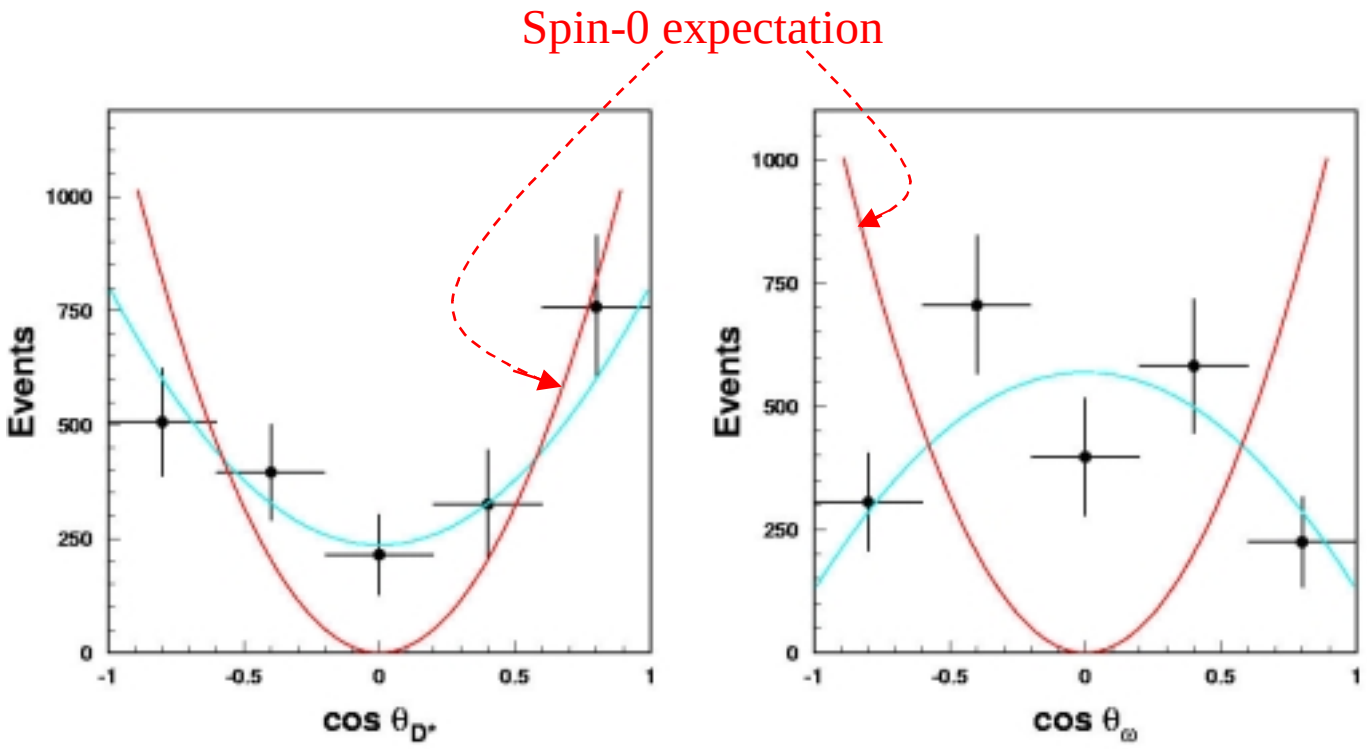
$D^{*\circ}\omega\pi^-$



Possible resonance (A) at M=1419±33 MeV, Γ=382±44 MeV

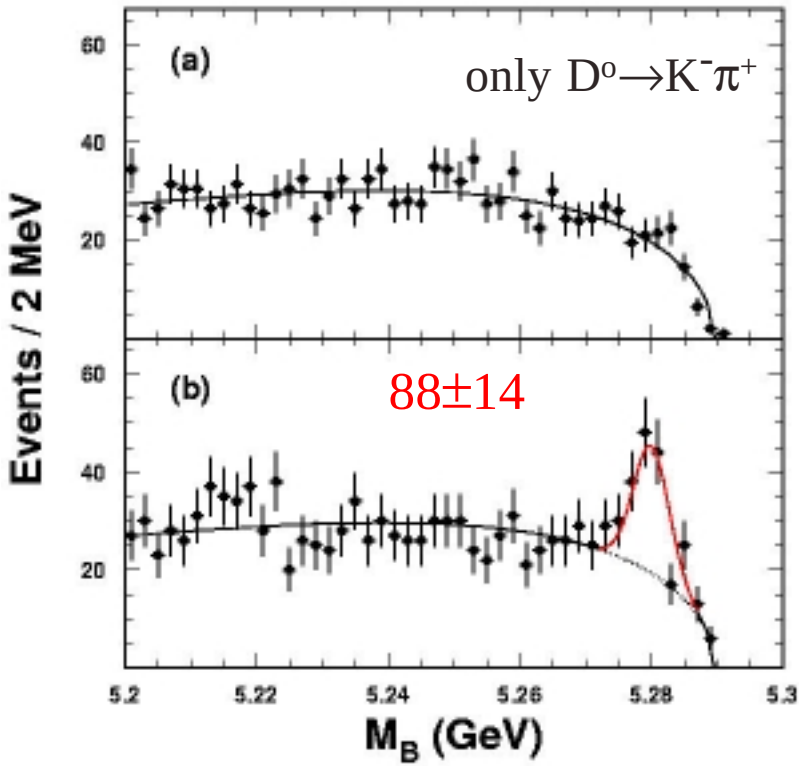
$D^{*+}(\omega\pi)^-$ Angular Distributions

- For a spin-0 A the D* & ω would be fully polarized
- Spin 0 $\Rightarrow \chi^2/dof$ = 3.5 ($\cos\theta_{D^*}$), 22 ($\cos\theta_\omega$) $\Rightarrow$ Ruled out
- Best fit $\Rightarrow$ Γ_L/Γ = 0.63±0.09 (D^{*+}), 0.10±0.09 (ω)

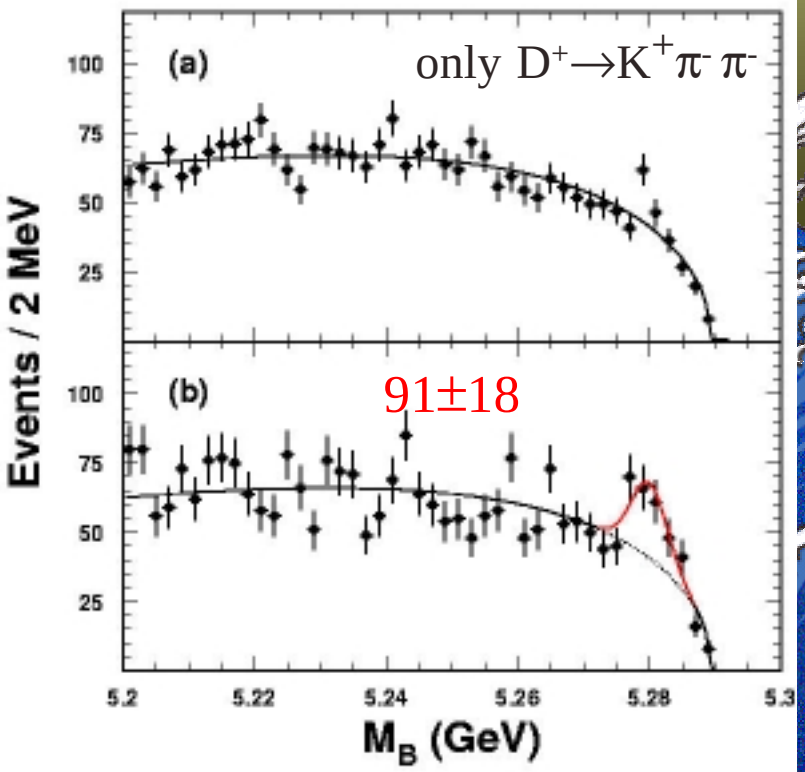


The Dωπ⁻ Final State

$D^{\circ}\omega\pi^{-}$

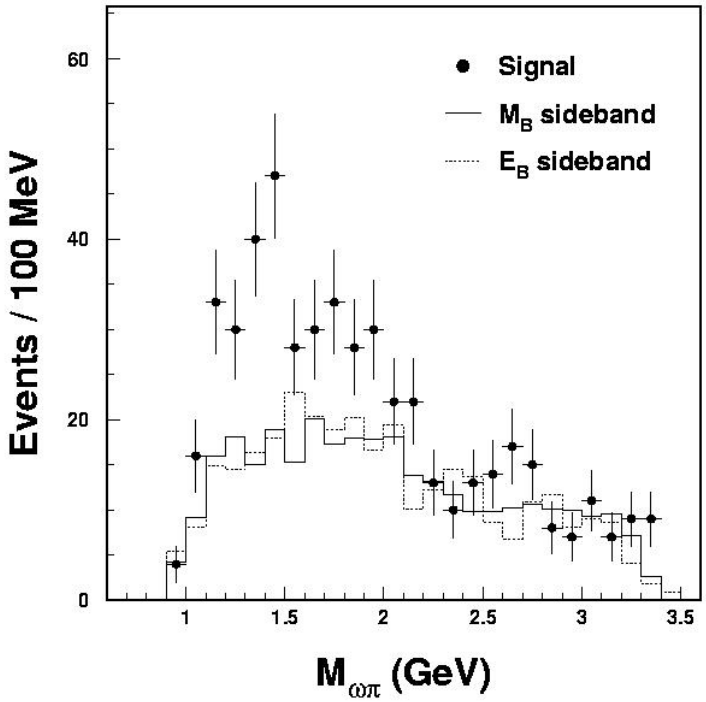


$D^{+}\omega\pi^{-}$

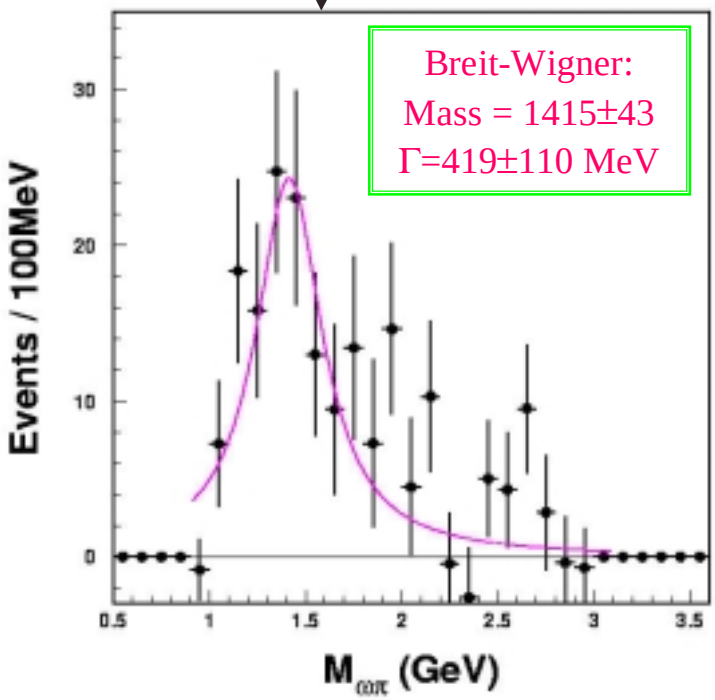


- Signal: $|\Delta E|<2\sigma$ (18MeV) Sideband: $3\sigma<|\Delta E|<7\sigma$
- No signal in ω sidebands

The $\omega\pi^-$ Mass Distribution



Fit M_B distribution in $\omega\pi$ mass bins

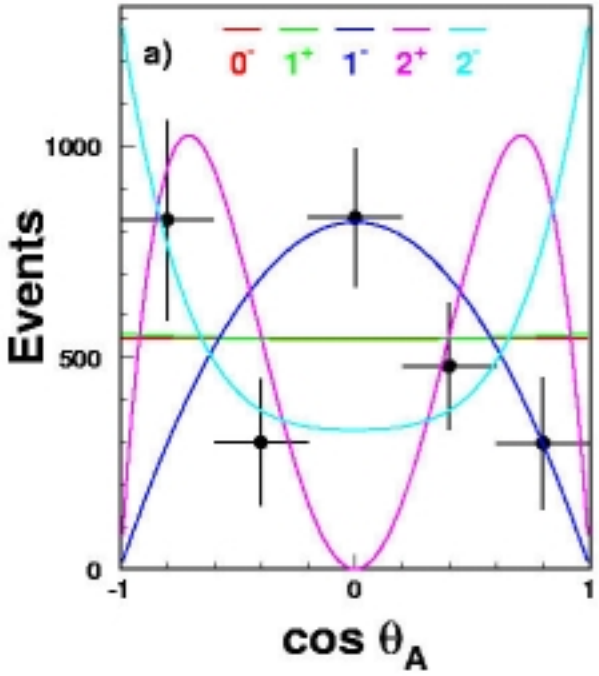


- Combined $D^0\omega\pi^-$ and $D^+\omega\pi^-$ modes (179 events)
- Consistent with $D^*\omega\pi$ result
- Select (1.1–1.7 GeV) for angular study (104 events)

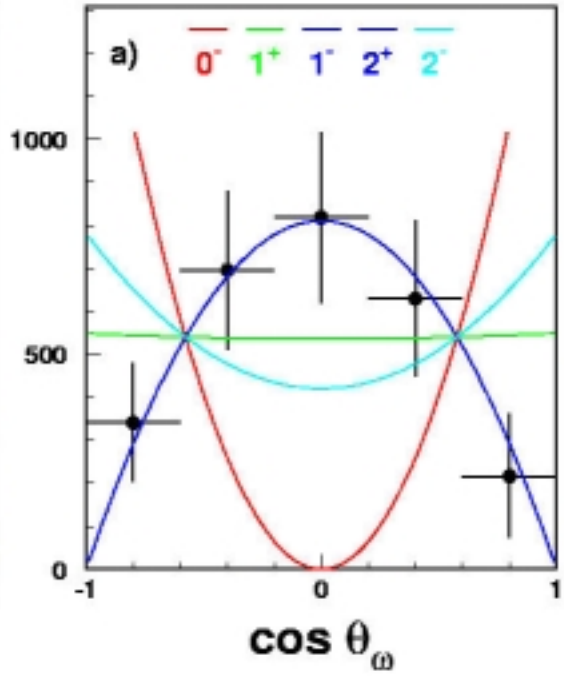
The Angular Distributions in

$B \to D A^-$: $A^- \to \omega \pi^-$, $\omega \to \pi^\circ \pi^+ \pi^-$

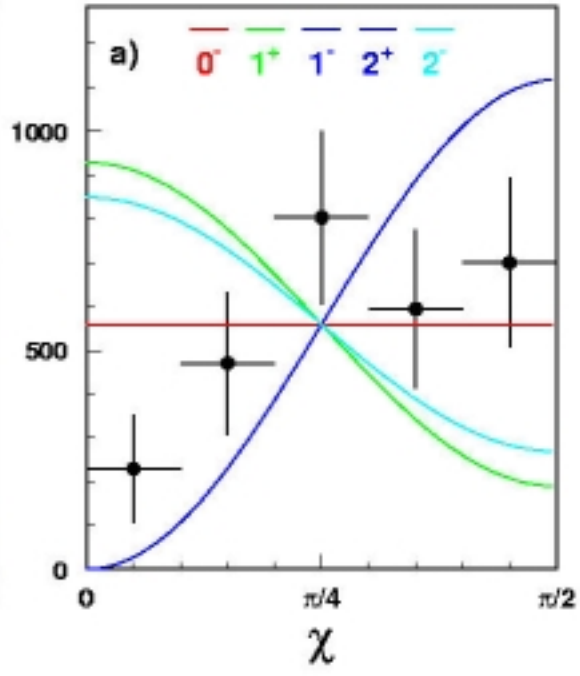
∠ between ω in A frame & A boost direction



∠ between normal of ω decay plane & ω boost



∠ between A & ω decay planes



- Small efficiency corrections applied
- For 1^+ and 2^-, the longitudinal ratio (Γ_L/Γ) floats
- 1^- preferred, χ^2/dof (1^-) = 1.7, (2^+) = 3.2
- A^- properties: mass = 1418±26±19 MeV, Γ=388±41±32 MeV

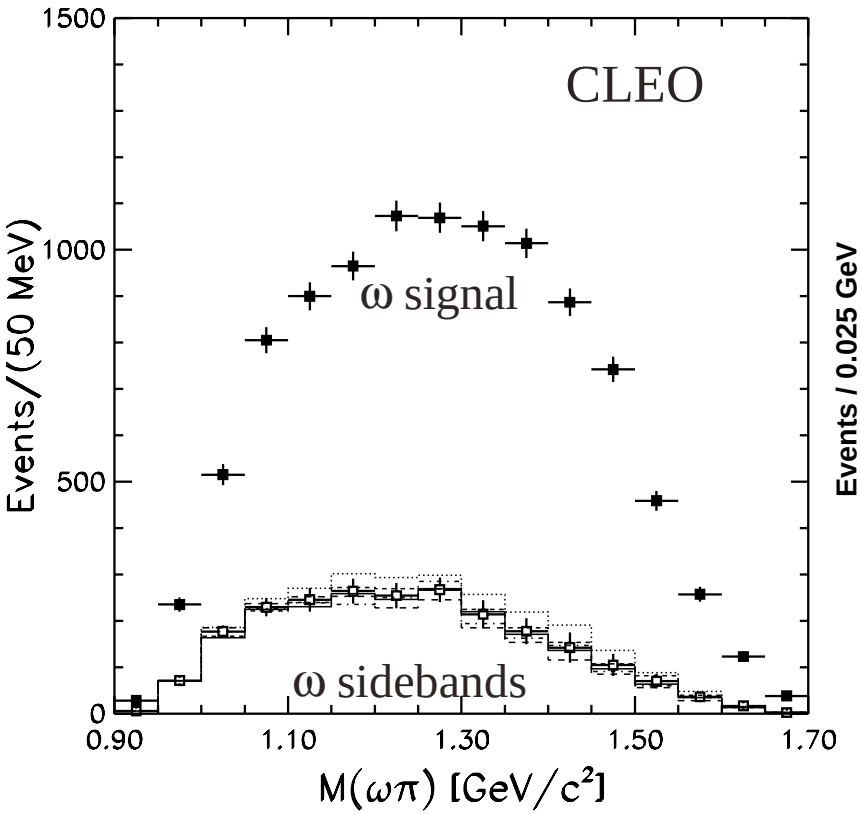
Identifying the A⁻ with the ρ′

- Clegg & Donnachie: ($\tau\to(4\pi)\nu$, $e^+e^-\to\pi^+\pi^-$, $\pi^+\pi^+\pi^-\pi^-$) find two 1^- states with (M, Γ)= (1463±25, 311±62) MeV & (1730±30, 400±100) MeV, mixed with non-$q\bar{q}$ states, only the lighter one decays to ωπ
- Godfrey & Isgur: Predict first radial excited ρ at 1450 MeV, Γ=320 MeV, $\mathcal{B}(\rho'^-\to\omega\pi^-)$=39%

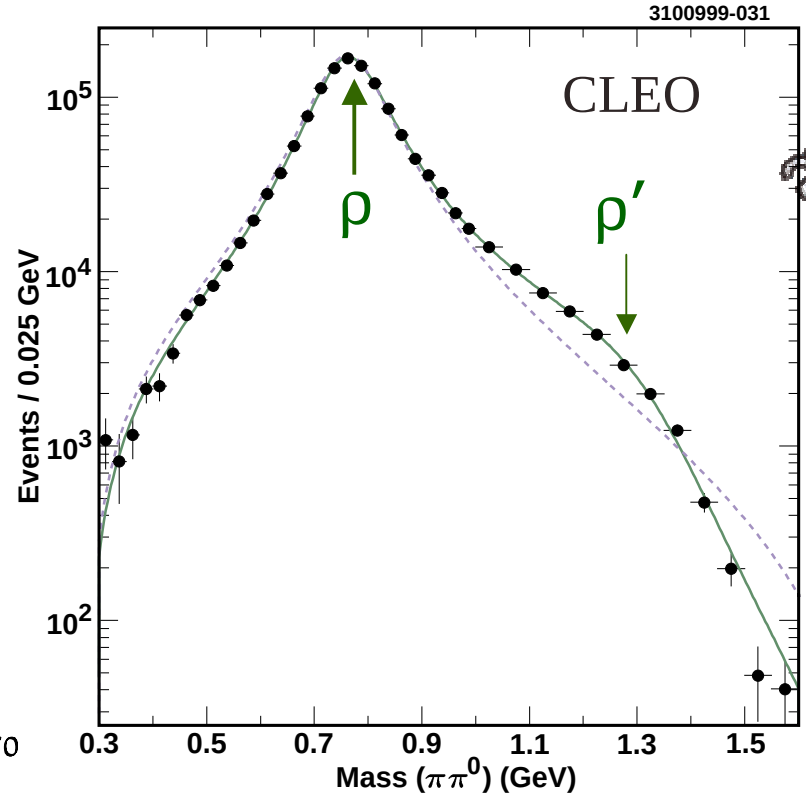
Recall, we measure: mass = 1418±26±19 MeV,
(Preliminary) Γ = 388±41±32 MeV

Evidence for ρ′ from τ Decay

$\tau^- \to \omega\pi^-\nu$



$\tau^- \to \pi^o\pi^-\nu$



Difficult to ascertain the Mass and Width

Summary & Discussion of Rates

Mode	Br (%)	# of events
$\overline{B}^0 \to D^{*+}\pi^0\pi^+\pi^-\pi^-$	1.72±0.14±0.24	1230±70
$\overline{B}^0 \to D^{*+}\omega\pi^-$	0.29±0.03±0.04	136±15
$\overline{B}^0 \to D^{+}\omega\pi^-$	0.28±0.05±0.03	91±18
$B^- \to D^{*0}\pi^0\pi^+\pi^-\pi^-$	1.80±0.24±0.25	195±26
$B^- \to D^{*0}\omega\pi^-$	0.45±0.10±0.07	26± 6
$B^- \to D^{0}\omega\pi^-$	0.41±0.07±0.04	88±14

- ρ' dominates the $\omega\pi^-$ final state
- $\Gamma(\overline{B}^0 \to D^{*+}\rho'^-) / \Gamma(B^0 \to D^{+}\rho'^-) = 1.04\pm0.21\pm0.06$
  $\Gamma(B^- \to D^{*0}\rho'^-) / \Gamma(B^- \to D^{0}\rho'^-) = 1.10\pm0.31\pm0.06$
  $\Gamma(B \to D^{*}\rho'^-) / \Gamma(B \to D\rho'^-) = 1.06\pm0.17\pm0.04$
- Consistent with Heavy Quark Symmetry prediction (ratio = 1)
- With $\mathcal{B}(\rho'^- \to \omega\pi^-)$=39%, $\Gamma(B \to D^{(*)}\rho'^-) \sim \Gamma(B \to D^{(*)}\rho^-)$

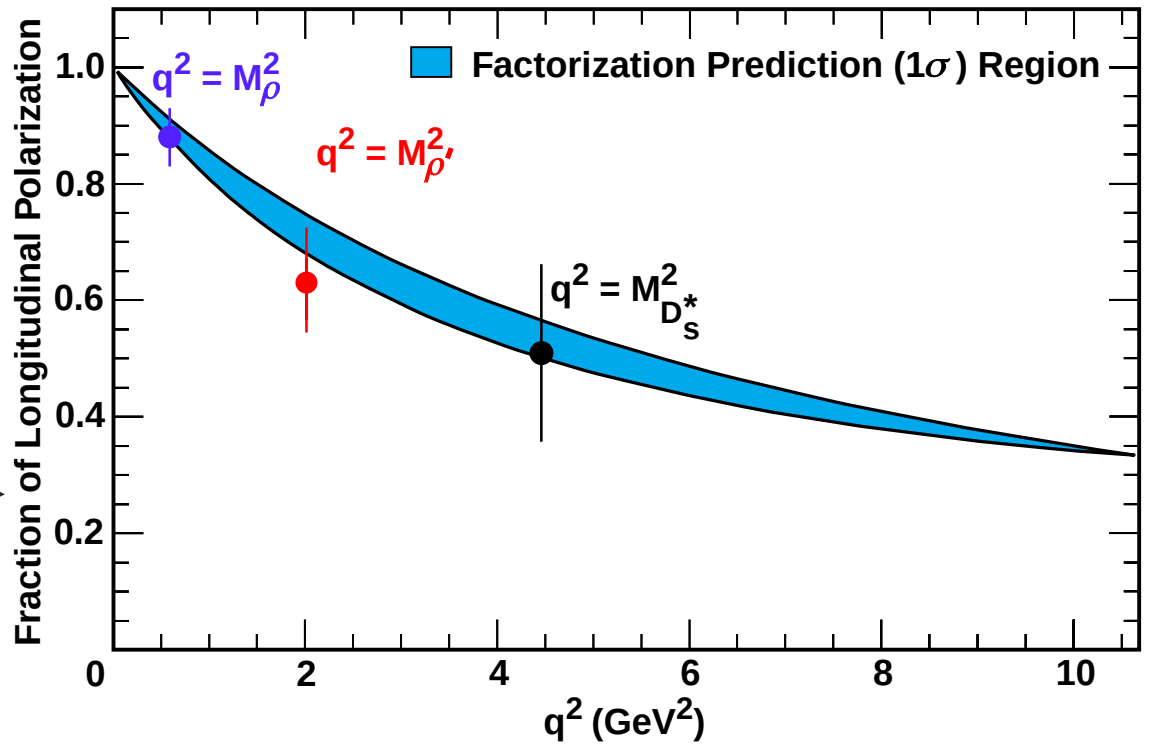
Factorization Tests Using Polarization

- $\Gamma_L/\Gamma\,(B\to D^{*+}h^-) \;=\; \Gamma_L/\Gamma\,(B\to D^{*+}l^-\nu)\big|_{q^2=m_h^2}$
- Also use new $B^o\to D^{*+}D_s^{*-}$, & old $D^{*+}\rho^-$ data

Final State	$\mathcal{B}$(%)
$D^{*+}D_s^-$	1.10±0.18±0.10±0.28
$D^{*+}D_s^{*-}$	1.82±0.37±0.24±0.46
$D_s^{*+}D^{**o}$	2.73±0.78±0.48±0.68

(Determined using partial reconstruction)

D^{*+} +	Γ_L/Γ (%)
ρ^-	87.8±5.3
ρ'^-	63 ± 9
D_S^{*-}	50.6±13.9±3.6



Using Factorization

- $\Gamma(B\to D^{*+}h^-) \,/\, d\Gamma/dq^2\,(B\to D^{*+}l^-\nu)|_{q^2=m_h^2} = 6\pi^2 c_1^2 f_h^2\,|V_{ud}|^2$, $c_1=1.1\pm0.1$
- Measurement:

  $f_{\rho'}^2\,\mathcal{B}(\rho'^-\to\omega\pi^-) = 0.011 \pm 0.003\ \mathrm{GeV}^2$
- Godfrey & Isgur predict:

  $\mathcal{B}(\rho'^-\to\omega\pi^-)=39\%$
- *Our measurment* $\Rightarrow$ $f_{\rho'} = 167 \pm 23\mathrm{MeV}$

Potpourri of Results Using Exclusive Charmonium Decays

- Y(4S) branching fractions using $B \to J/\psi K^{(*)}$

$$\frac{f_{oo}}{f_{+-}} = \frac{\mathcal{B}(\Upsilon(4S) \to B^o \bar{B}^o)}{\mathcal{B}(\Upsilon(4S) \to B^- B^+)} = 1.04 \pm 0.07 \pm 0.04$$

Yields: $f_{oo}=0.49\pm0.02\pm0.01$, $f_{+-}=0.51\pm0.02\pm0.01$

- $\mathcal{B}(B^+ \to \eta_c K^+) = (6.9^{+2.6}_{-2.1} \pm 0.8 \pm 2.0) \times 10^{-2}$

$\mathcal{B}(B^o \to \eta_c K^o) = (10.9^{+5.5}_{-4.2} \pm 1.2 \pm 3.1) \times 10^{-2}$

Yields, using factorization f_{η_c} = 335±75 MeV

- No CP asymmetry observed in
  - $\frac{\Gamma(J/\psi K^+) - \Gamma(J/\psi K^-)}{\Gamma(J/\psi K^+) + \Gamma(J/\psi K^-)} = (1.8 \pm 4.3 \pm 0.4)\%$
  - $\frac{\Gamma(\psi' K^+) - \Gamma(\psi' K^-)}{\Gamma(\psi' K^+) + \Gamma(\psi' K^-)} = (2.0 \pm 9.1 \pm 1.0)\%$

Conclusions

- Large ~ 1.8% branching rate $D^*\pi^+\pi^-\pi^-\pi^o$ modes have been found
- ρ' seen for first time in B decays (hep-ex/0006018)
  - Coupling large, may be similar to ρ
  - ***Preliminary*** values for ρ'mass and width: $M=1418\pm26\pm19$ MeV, $\Gamma=388\pm44\pm32$ MeV
- Factorization tests involving spin symmetry and polarization work for $D^{*+}\rho$, ρ', and D_S^*
- Ratio of charged/neutral B production at Y(4S) nearly equal.
- No anomalies in charmonium decays found
  - No unexpected large CP asymmetries in $\psi^{(\prime)}K^{\pm}$
  - "Reasonable" rate for $\eta_C K$ final states ~J/ψ K