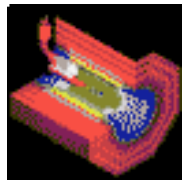
CORNELL UNIVERSITY LEPP

LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS



B Hadronic Decays at CLEO

One last look ?

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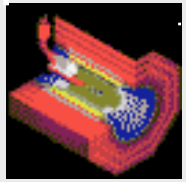
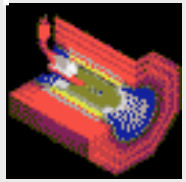


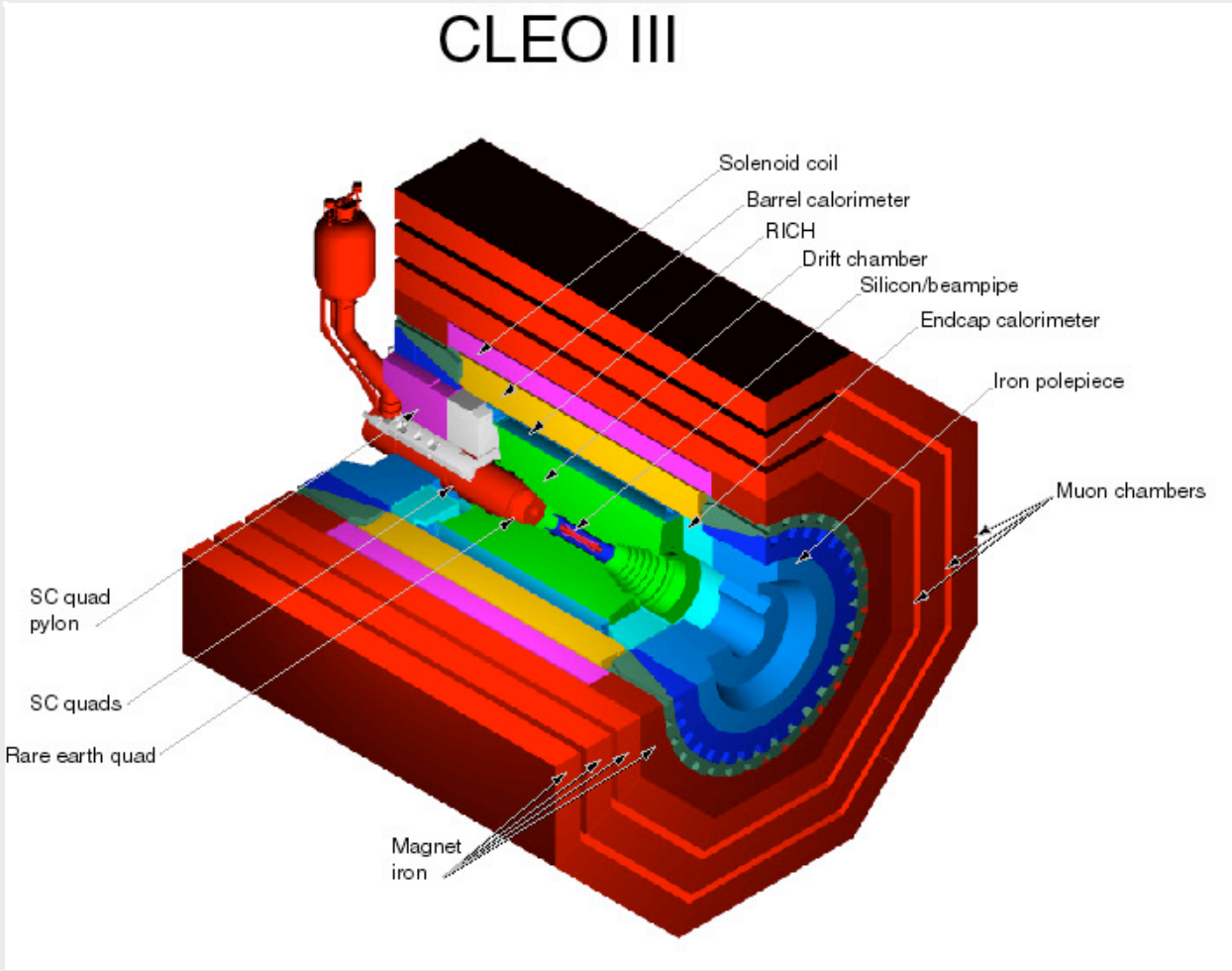
Outline

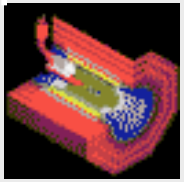
- CLEO for the novice
- Two Body Rare B Decays
  - hep-ex/030202
- BR(B → DK)/BR(B → D□)
  - hep-ex/030202
- B → D*□ - Branching Ratio, Helicity Amplitude, Factorization
  - hep/ex 0301028
- Charge Asymmetry in $B^0 \rightarrow K^*$□



The CLEO Detector

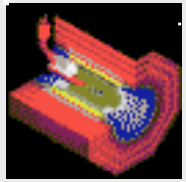
- CLEO2
  - DR, dEdx, TOF, CC, MU
- CLEO2.5
  - 3 layer Si detector
  - He/Propane DR gas
- CLEO3
  - RICH+dEdx PID
  - New DR
  - 4 layer Si





Rare B Decays

- B^0 to $\pi\pi$, $K\pi$, KK B^+ to $\pi\pi^0$, $K\pi^0$
- B^0 to $K^0\pi^0$, K^0K^0, $\pi^0\pi^0$ B+ to πK^0, KK^0
- B^0 to $p\bar{p}$, $\pi\bar{\pi}$ B^+ to $p\bar{\pi}$
- hh provides insight into γ via interference
- Door for new New physics via Penguin Diagrams
- Independent from charm final states
- Use CLEO2 + CLEO3 data = 15 fb^{-1}

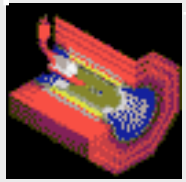


Rare B: The Method

- Hard Selection of final states
  - Track, shower, π^0 quality cuts
  - M_B and ΔE, $\cos(\theta_{sphericity})$ cuts
  - PID: combine RICH, dEdx
- Maximum Likelihood extraction of signal
  - use M_B, ΔE, B direction, Fisher

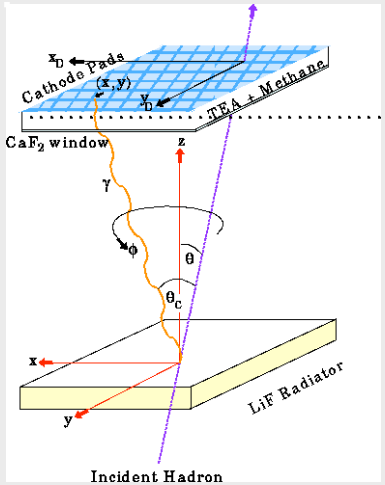
$$\Delta E = E - E_{Beam}$$

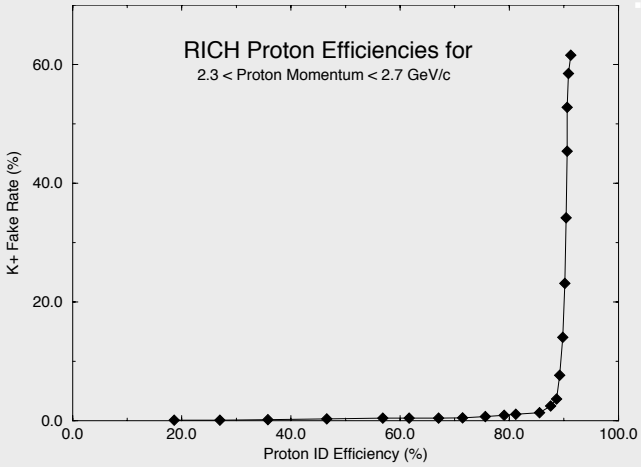
$$M_B = \sqrt{(E^2_{Beam} - \Sigma \vec{p_i})}$$

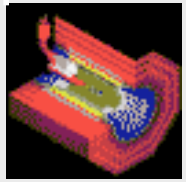


Rare B: Particle ID

- K/Pi :Combine RICH, dEdx
  - ΔL = ΔL(RICH) + ΔL(dEdx)
  - Calibrated using Data D* (→ (Kπ)π)
  - ϒ(4s) at rest – Momentum of interest 2.5 GeV
  - Chose cut to accept 90 % of π/K
    - Fake rate = 11% π faking K, 8 % K faking π
- K/p : Use only RICH
  - Calibrate on Λ to pπ, D*(→ (Kπ)π) sample
  - p acceptance 76 % pbar = 72%
  - Fake rate: K fake p = 1 %



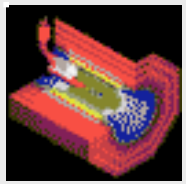




Rare B: The Fit

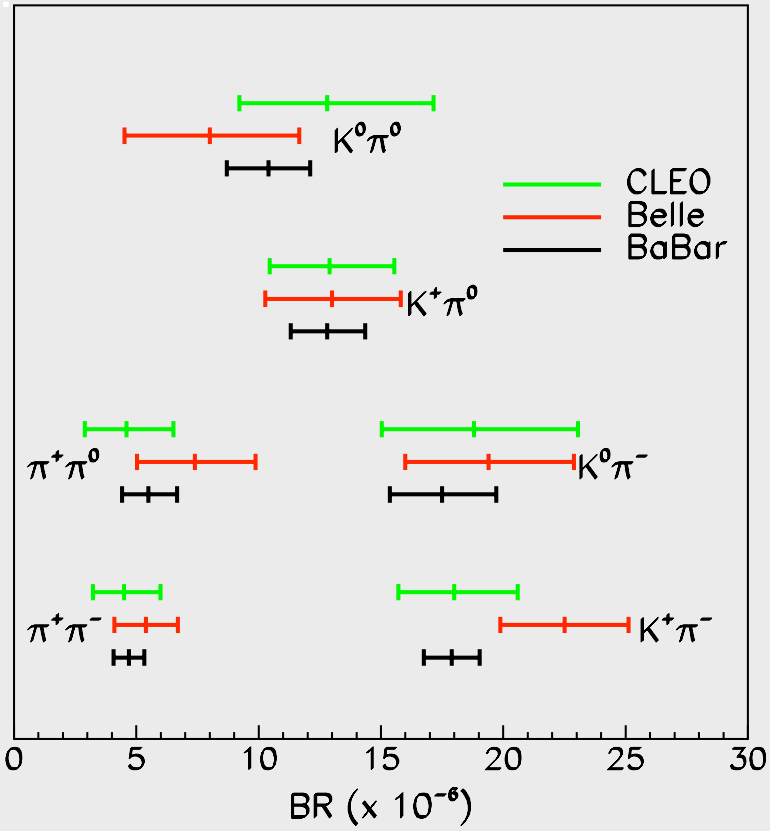
- Extended Maximum Likelihood Fit
- Probability Product for M_B, ΔE, B direction, Fisher
  - for each of 13 signals, cross feeds from other B modes, and qqbar background
- Fisher:
  - linear combination of
    - direction of thrust axis of candidate
    - 9 Virtual Calorimeter Bins
    - Momentum of highest e, , K, p in event
  - Signal Fisher from MC
  - Background Fisher used in all modes
  - 1.4 σ separation

Virtual Calorimeter: Scalar sum of momenta in 10^0 bins around candidate sphericity axis



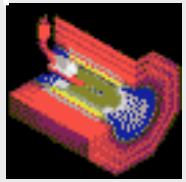
Rare B: Results

	CLEO II		CLEO III		Combined	
Mode	Significance	$\mathcal{B}\times10^6$	Significance	$\mathcal{B}\times10^6$	Significance	$\mathcal{B}\times10^6$
$\pi^+\pi^-$	4.2	$4.3^{+1.6+0.5}_{-1.4-0.5}$	2.6	$4.8^{+2.5+0.8}_{-2.2-0.5}$	4.4	$4.5^{+1.4+0.5}_{-1.2-0.4}$
$\pi^+\pi^0$	3.2	$5.6^{+2.6+1.7}_{-2.3-1.7}$	2.1	$3.4^{+2.8+0.8}_{-2.0-0.3}$	3.5	$4.6^{+1.8+0.6}_{-1.6-0.7}$
$\pi^0\pi^0$	2.0	(<5.7)	1.8	(<7.6)	2.5	(<4.4)
$K^+\pi^-$	12	$17.2^{+2.5+1.2}_{-2.4-1.2}$	>7	$19.5^{+3.5+2.5}_{-3.7-1.6}$	>7	$18.0^{+2.3+1.2}_{-2.1-0.9}$
$K^0\pi^+$	7.6	$18.2^{+4.6+1.6}_{-4.0-1.6}$	4.6	$20.5^{+7.1+3.0}_{-5.9-2.1}$	>7	$18.8^{+3.7+2.1}_{-3.3-1.8}$
$K^+\pi^0$	6.1	$11.6^{+3.0+1.4}_{-2.7-1.3}$	5.0	$13.5^{+4.0+2.4}_{-3.5-1.5}$	>7	$12.9^{+2.4+1.2}_{-2.2-1.1}$
$K^0\pi^0$	4.9	$14.6^{+5.9+2.4}_{-5.1-3.3}$	3.8	$11.0^{+6.1}_{-4.6}\pm2.5$	5.0	$12.8^{+4.0+1.7}_{-3.3-1.4}$
K^+K^-	-	(<1.9)	-	(<3.0)	-	(<0.8)
K^0K^-	-	(<5.1)	-	(<5.0)	-	(<3.3)
$K^0\overline{K^0}$	-	(<6.1)	-	(<5.2)	-	(<3.3)
$p\bar{p}$	-	(<7.0)	-	(<1.4)	-	(<1.4)
$p\bar{\Lambda}$	-	(<2.0)	-	(<3.2)	-	(<1.5)
$\Lambda\bar{\Lambda}$	-	(<1.8)	-	(<4.2)	-	(<1.2)



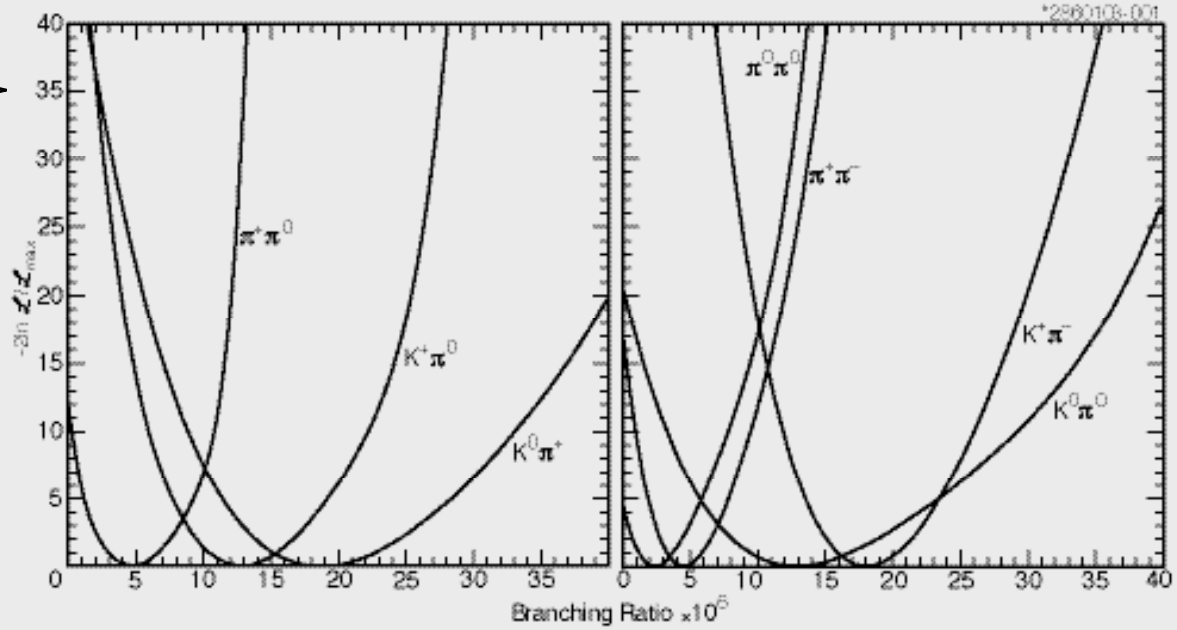
Largest Systematics: Λ, π^0, K_s, N(B) << σ(stat)

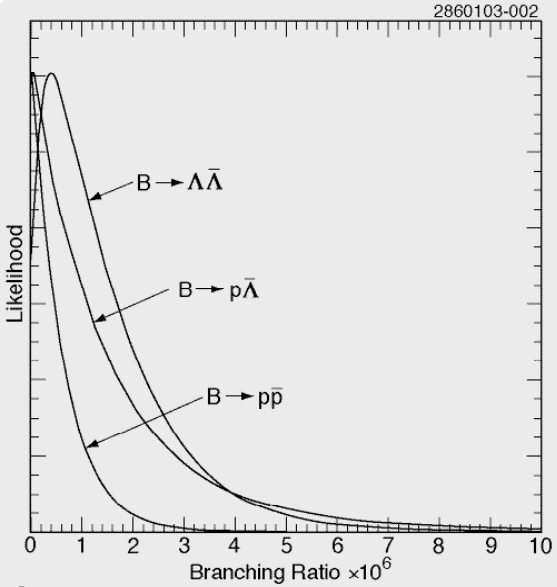
CLEO results still competitive to BaBar and Belle



Rare B: Likelihoods

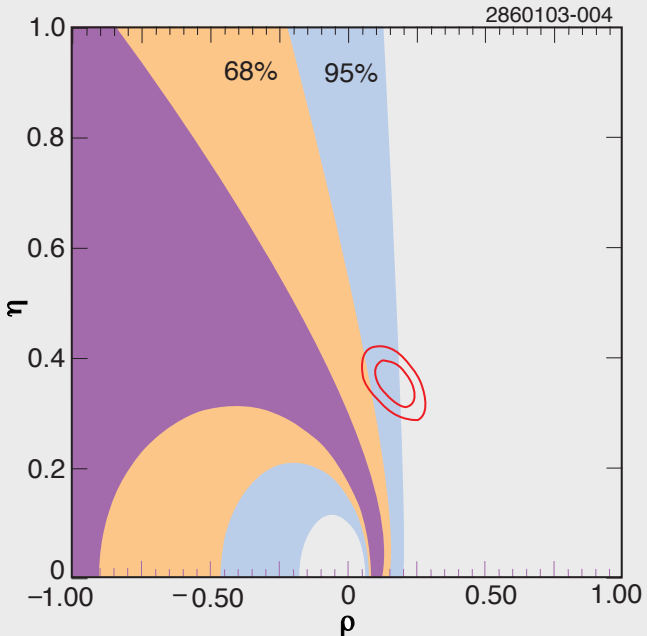
Meson
-2ln(Likelihood)

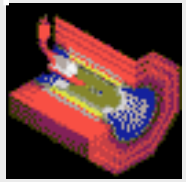




Baryon
Likelihood

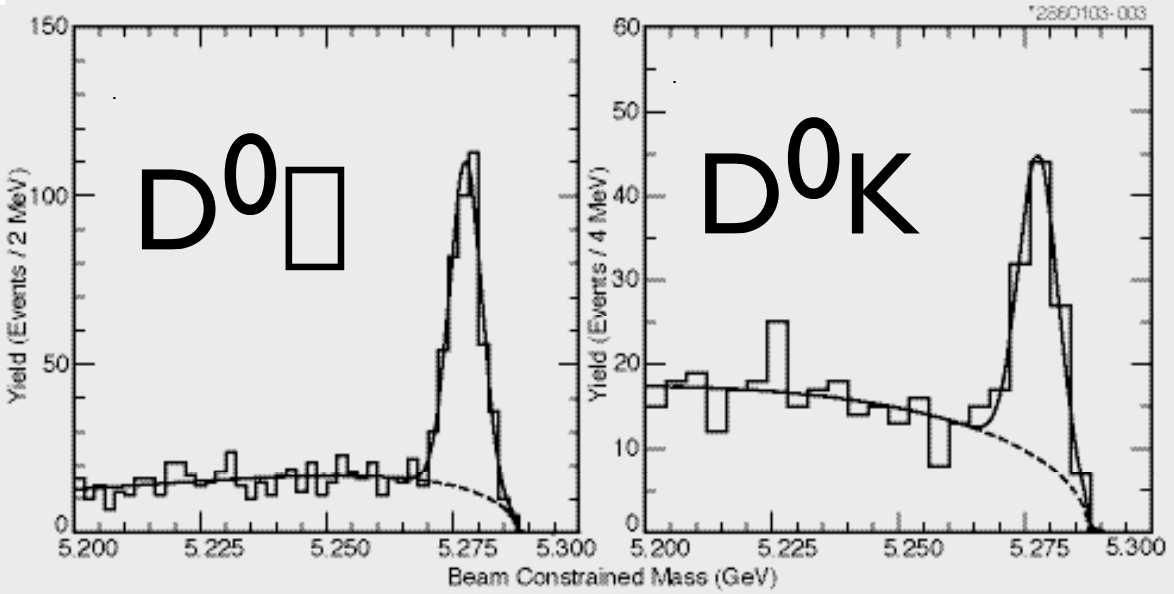
Combined Belle, BaBar, CLEO derived limits on γ from ππ and Kπ decays



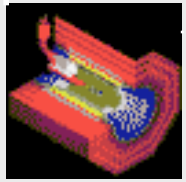


$B^- \to D^0 K$/ $B^- \to D^0 \pi$

- CLEO3 data
- PID on fast π, K
- Account for pion contamination in K channel
- Small PID syst



$$\frac{Br(B^- \to D^0 K^-)}{Br(B^- \to D^0 \pi^-)} = (9.9^{+1.4+0.7}_{-1.2-0.6}) \times 10^{-2}$$



B → D* ρ: Branching Ratios

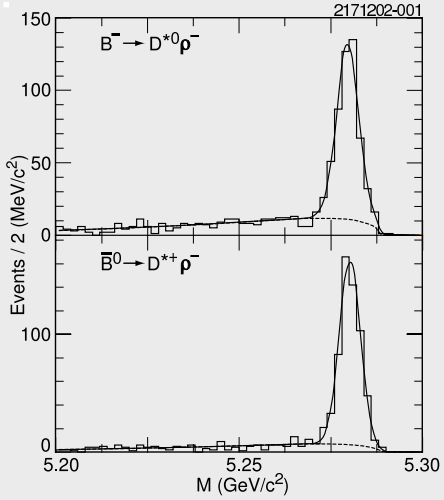
cleo2 data - 9 fb^{-1}

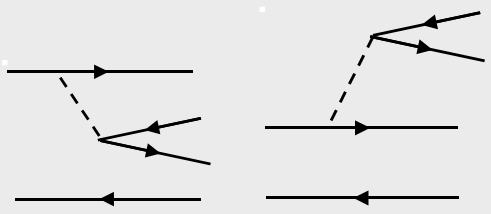
Do Extended Max Likelihood fit for M(B), m(ρ), for both Signal and Background to get N(B)

$$\mathcal{B}r(B^- \to D^{*0}\rho^-) = (0.98 \pm 0.06 \pm 0.16 \pm 0.05)\%$$

$$\mathcal{B}r(\overline{B}^0 \to D^{*+}\rho^-) = (0.68 \pm 0.03 \pm 0.09 \pm 0.02)\%$$

1st syst π^0 reconstruction dominates - 2nd syst: D, D BR errors:*

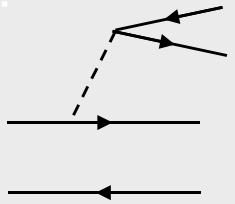




$B^- \to D^{*0}\rho^-$

BSW Effective couplings:
color enhanced a1
color suppressed a2

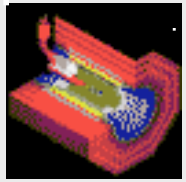
$$\frac{\mathcal{B}r(B^- \to D^{*0}\rho^-)}{\mathcal{B}r(\overline{B^0} \to D^{*+}\rho^-)} \approx (1 + 0.75 a_2/a_1)^2$$



$\overline{B^0} \to D^{*+}\rho^-$

$$a_2/a_1 = 0.21 \pm \pm 0.03 \pm 0.05 \pm 0.04 \pm 0.04$$

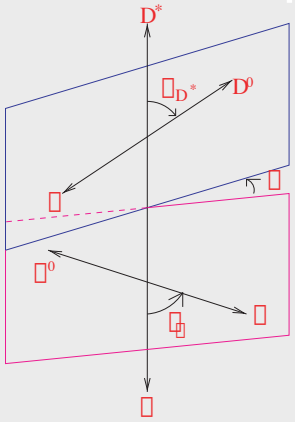
last syst is from f_{+-}/f_{00}



B → D* ρ: Helicity Amplitudes

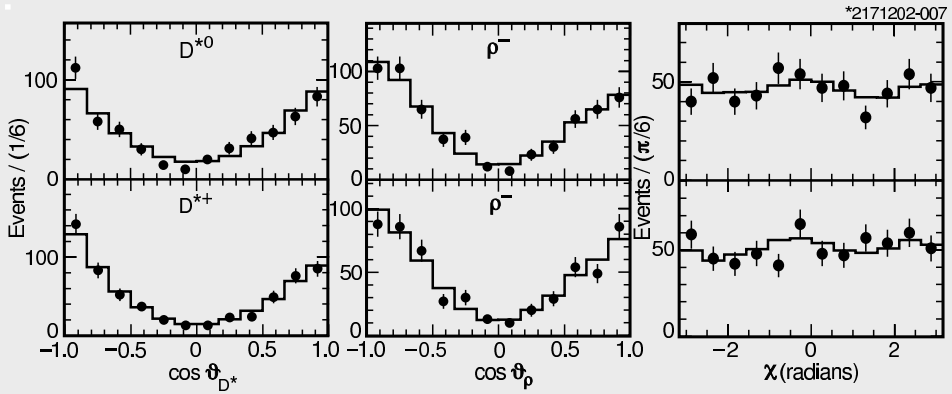
Decay can be described by Helicity Amplitudes H(-,0,+)

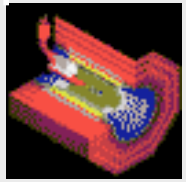
$$\frac{d^3\Gamma}{d\cos\theta_{D^*}d\cos\theta_\rho d\chi} = \frac{9}{32\pi}\left|2H_0\cos\theta_{D^*}\cos\theta_\rho + 2\left(H_+e^{i\chi} + H_-e^{-i\chi}\right)\sin\theta_{D^*}\sin\theta_\rho\right|^2$$



$$\frac{\Gamma_L}{\Gamma} = \frac{|H_0|^2}{|H_0|^2+|H_+|^2+|H_-|^2} = 1 - \frac{\Gamma_T}{\Gamma}$$

Do Extended Max Likelihood fit for
M(B), m(ρ),
dΓ*ϵ(χ,cos(θ(D*),cos(θ(ρ)))
for both Signal and Background





B → D* ρ: Helicity – Factorization

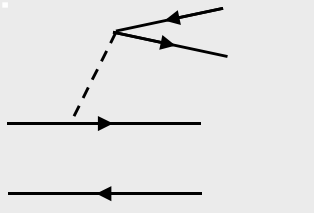
	D*0	D*+
|H0|	0.944±0.009±0.009	0.941±0.009±9.006
|H+|	0.122±0.040±0.010	0.107±0.031±0.011
α+	1.02±0.28±0.11	1.42±0.27±0.04
|H-|	0.306±0.030±0.025	0.322±0.025±0.016
α−	0.65±0.16±0.04	0.31±0.12±0.04

α: Possible Phase of H - sensitive to FSI

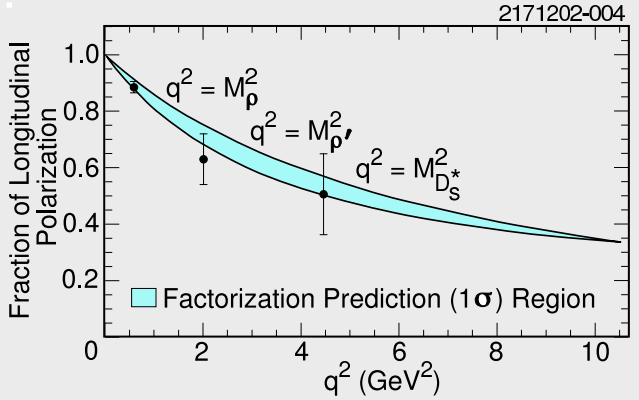
$$\frac{\Gamma_L}{\Gamma}(\overline{B}^0 \to D^{*+}\rho^-) = 0.885 \pm 0.016 \pm 0.012$$

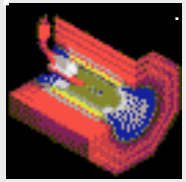
$$\frac{\Gamma_L}{\Gamma}(B^- \to D^{*0}\rho^-) = 0.892 \pm 0.018 \pm 0.016$$

$$\frac{\Gamma_L}{\Gamma}(\overline{B}^0 \to D^{*+}\rho^-) = \frac{\Gamma_L}{\Gamma}(\overline{B}^0 \to D^{*+}l^-\overline{\nu})_{q^2=M_\rho^2}$$



$\overline{B^0} \to D^{*+}\rho^-$





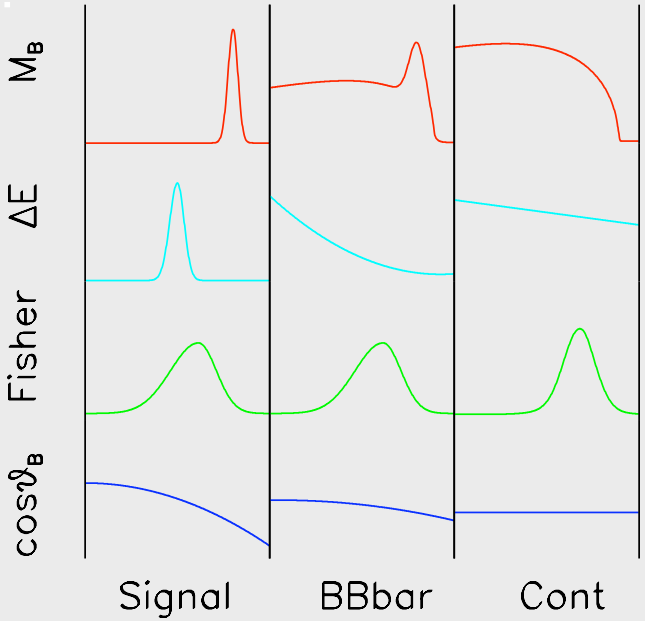
Charge Asymmetry in $B^0 \to K^*\pi$

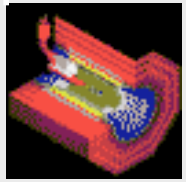
$$\mathcal{A}_{CP} = \frac{\mathcal{B}(\overline{B}^0 \to K^*(892)^-\pi^+) - \mathcal{B}(B^0 \to K^*(892)^+\pi^-)}{\mathcal{B}(\overline{B}^0 \to K^*(892)^-\pi^+) + \mathcal{B}(B^0 \to K^*(892)^+\pi^-)}$$

- CLEO2 data - 9 fb^{-1}
- Final States: $K_s\ h^{+/-}\ \pi^{+/-}$, $K^{+/-}\ h^{+/-}\ \pi^0$

  Actually measure A_{+-} - 99.99% correlated with A_{CP} for this decay
- Max Likelihood fit to M_B, ΔE, Dalitz Plot, $dEdx(h^{+/-})$, B decay angle, Fisher

  Fisher is l.c. of Virtual Calorimeter, Fox-Wolfram R2, sphericity angle
  - include K*+(892) π-/K-, K*+(1430) π-/K-, ρ0 Ks0, f0(980)Ks, Ks π π/K NR, K*0(892)π0, K*0(1430) π0, K-π+π0 NR
    exclude B → D π, ψ Ks, ψ π^0 background slices





Charge Asymmetry in $B^0 \to K^*\pi$

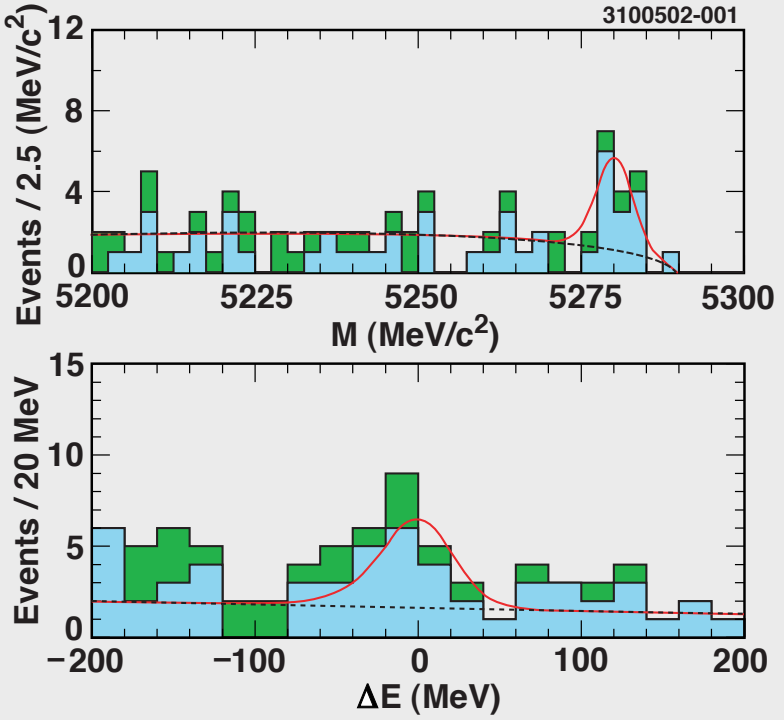
$$\mathcal{A}_{CP}(B \to K^{*\pm}(892)\pi^{\mp}) = 0.26^{+0.33+0.16}_{-0.34-0.15}$$

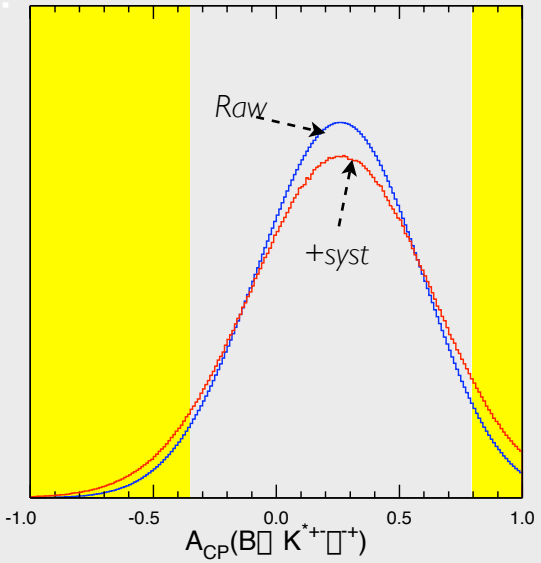
90% C.L.:

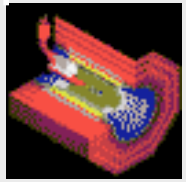
$$-0.35 < \mathcal{A}_{CP}(B \to K^{*\pm}(892)\pi^{\mp}) < 0.79$$

Theory: [14,47]% QCDF, -19% PQCD

Dominant Systematic:
interference terms
between signal yields







Conclusions

- Presented competitive results on 2 body rare B decay modes
  - Hint that γ might not agree with standard CKM fits
- Presented competitive $B \rightarrow DK/B \rightarrow D\pi$ result
- Explored Helicity Amplitudes, BSW coefficients, factorization in $B \rightarrow D^* \rho$
- First limits on A_{CP} in $B \rightarrow K^* \pi$

☮ We're done making B's !

CLEO-c kick off June 2003

http://www.lns.cornell.edu/public/CLEO/spoke/CLEOc

Bon Appétit !