CLEO D and B Results

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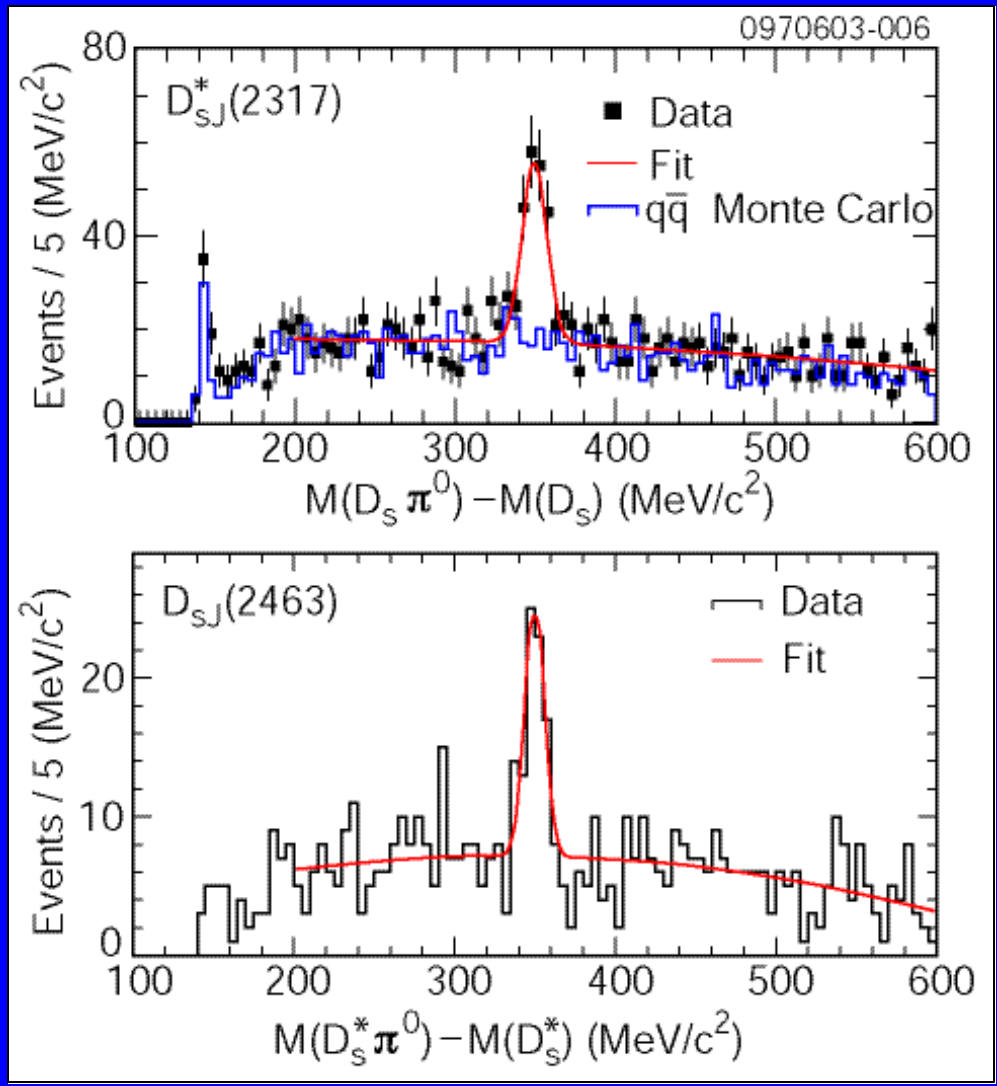
New $c\bar{s}$ States

- $c\bar{s}$ spectrum: consider quark spins and L: $j=L+S_q$
  - $J^P=0^-$ $D_s^+(1968)$; ground state decays weakly
  - $J^P=1^-$ $D_s^{*+}(2112)$; decays to $D_s\gamma$ (94%), $D_s\pi^0$ (6%)
  - $J^P=1^+$ $D_{s1}^+(2536)$; decays to D*K, narrow $\Gamma<2$ MeV
  - $J^P=2^+$ $D_{sJ}^{*+}(2573)$; decays to DK, narrow $\Gamma=15$ MeV
- Should also be $j=½$, 0^+, 1^+ states, expected to decay to $D^{(*)}K$ by S-wave and therefore broad
- Narrow peak recently seen by BaBar in $D_s\pi^0$
- What might this be: 0^+, 1^+? DK Molecules? $q\bar{q}q\bar{q}$?

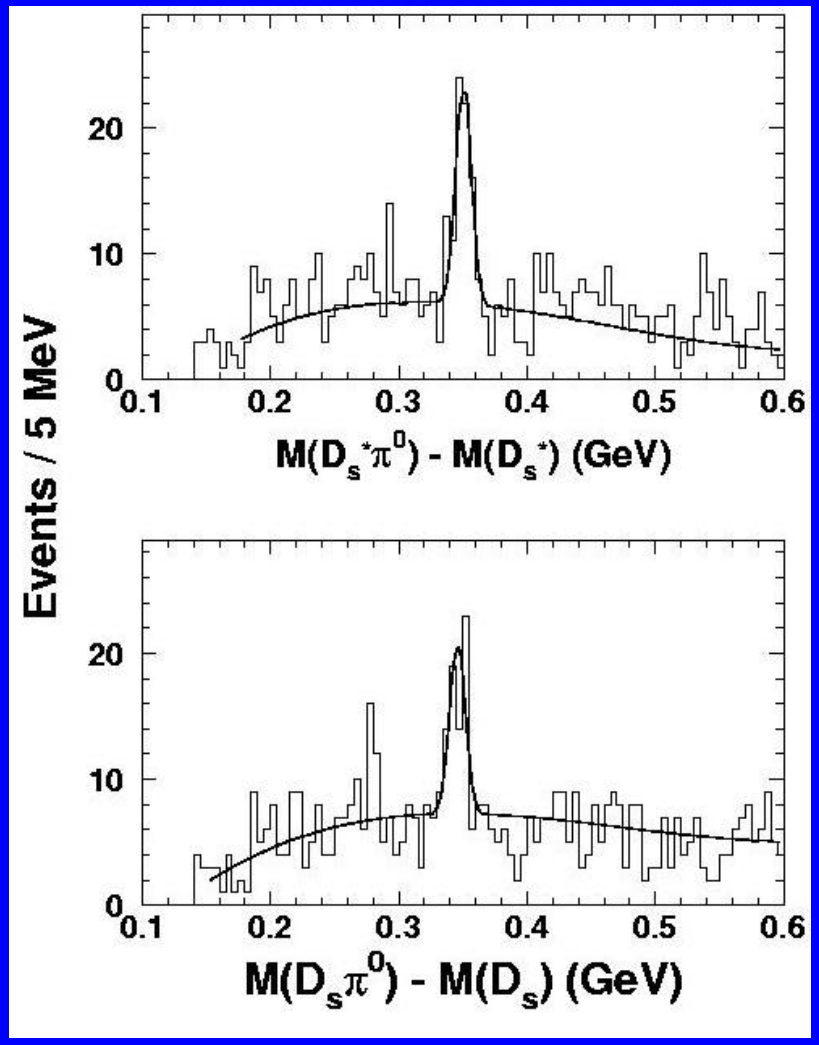
CLEO Sees Two States

PRD68, 032002 (2003)

- Confirms the BaBar observation of $D_s(2317)$
  - σ = 8.0±1.3 MeV
  - Detector resolution: 6.0±0.3 MeV → Γ<7 MeV
  - 165±20 events in peak
- Finds 2nd state decaying into $D_s^*\pi^0$, at 2463 MeV
  - σ = 6.1±1.0 MeV
  - Detector resolution: 6.6±0.5 MeV → Γ<7 MeV
  - 55±10 events in peak



Are there really two?

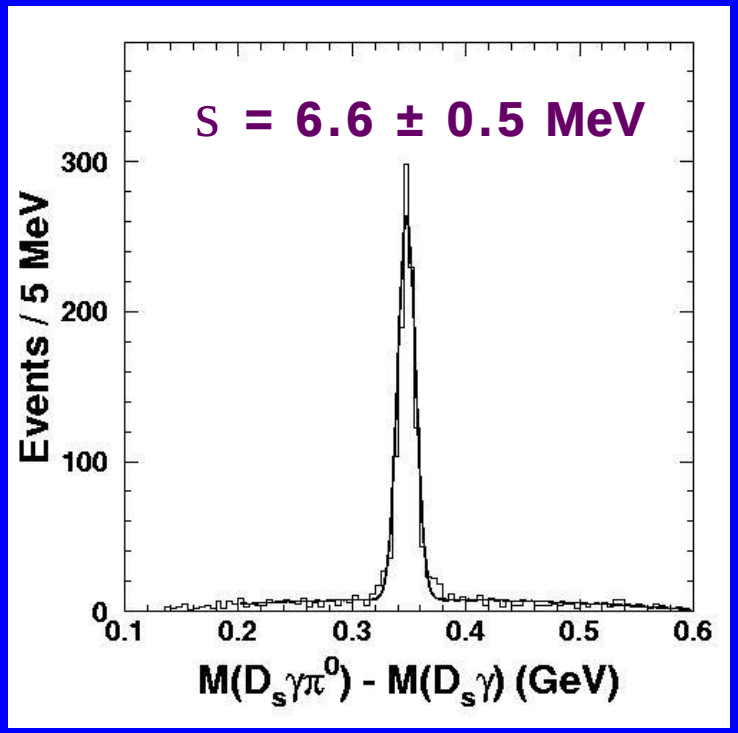


- 350 MeV ΔM is nearly the same
- Missed photon in $D_s^* \rightarrow D_s\gamma$ & 2463 mimics 2317
- Take $D_s(2463)$ candidates and plot $M(D_s\pi^0) - M(D_s)$:
  - Feeds down to 2317
  - Broader peak σ = 15 MeV

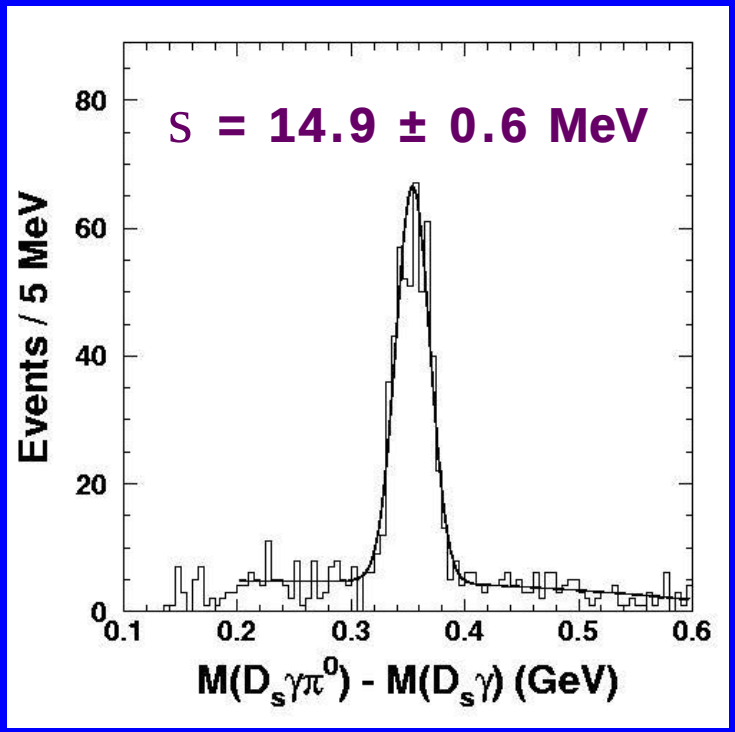
Feed Up From 2317 → 2463

MC Simulation

$D_s(2463) \rightarrow D_s^* \pi^0$ Signal

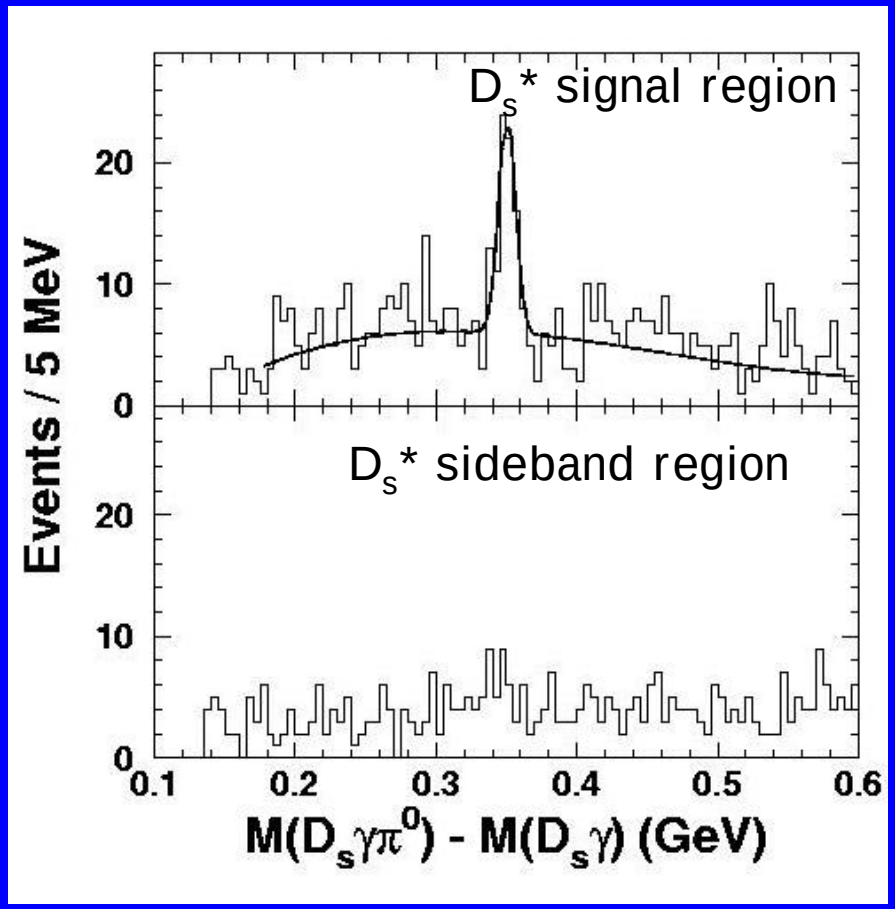


$D_s(2317) \rightarrow D_s \pi^0$ Signal + Random γ



$D_s(2317)$ does "feed up" to the $D_s(2463)$ by attaching to a random γ. Low probability of (9.0±1.7)%, wide peak.

Establishing Both States



- 2 states established in multiple ways:
- Account for crossfeed using MC and data
  - N(2317)=155±23
  - N(2463)=41±12
- Look at D_s* sideband
  - sb-subtracted fit: 5.7 σ
- Fit 2317 peak w/ wide & narrow Gaussians

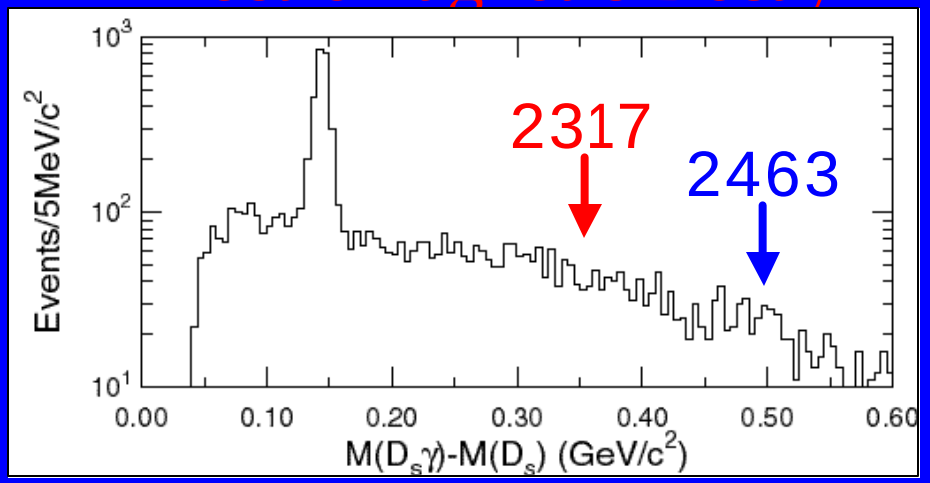
3 techniques agree:

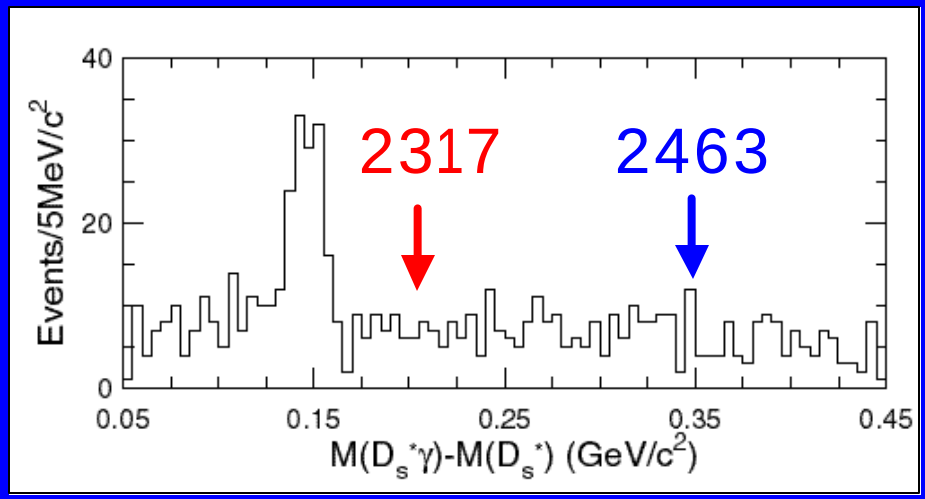
There are two states.

Searches for other D_{sJ} decays

- To aid interpretation of new states, other decay modes helpful
- Look for $D_{sJ}^*(2317)$ decays to $D_s^{(*)}\gamma$, $D_s^*\pi$ & $D_s\pi\pi$
- Look for $D_{sJ}(2463)$ decays to $D_s^{(*)}\gamma$, $D_s\pi$ $D_{sJ}^*(2317)\gamma$ & $D_s\pi\pi$

Electromagnetic Decay





Limits on other decay modes

$B/D_s\pi^0$

2317

Mode	Yield	90% CL	Thry
$D_s\pi^0$	150±49	-	=1
$D_s^*\pi^0$	-1.7±3.9	<0.11	0
$D_s\gamma$	-22±13	<0.052	0
$D_s^*\gamma$	-2.0±4.1	<0.059	0.08
$D_s\pi^+\pi^-$	1.6±2.6	<0.019	0

$B/D_s^*\pi^0$

2463

Mode	Yield	90% CL	Thry
$D_s^*\pi^0$	41±11	-	=1
$D_s\gamma$	40±17	<0.49	0.24
$D_s^*\gamma$	-5.1±7.7	<0.16	0.22
$D_s\pi^+\pi^-$	2.5±5.4	<0.08	0.20
$D_s(2317)\gamma$	3.6±3.0	<0.58	0.13

- Lack of $D_{sJ}^*(2317) \rightarrow D_s^*\pi^0$ evidence for 0^+
- Lack of $D_{sJ}(2463) \rightarrow D_s\pi^0$ and DK supports interpretation as 1^+
- Other limits consistent with theory for $0^+,1^+$
- $D_{sJ}(2463) \rightarrow D_s\pi^+\pi^-$ expected (OZI) but not seen yet (<8% $D_s\pi^0$)
- Consistent interpretation as 0^+ and 1^+ $c\bar{s}$ mesons
- More exotic explanations

First Search for $D^0 \to \gamma\gamma$

FCNC D decay

SM Prediction: $\approx 10^{-8}$

Burdman, Golowich, Hewett,

Pakvasa PRD66, 014009 (2002)

CLEO Results:

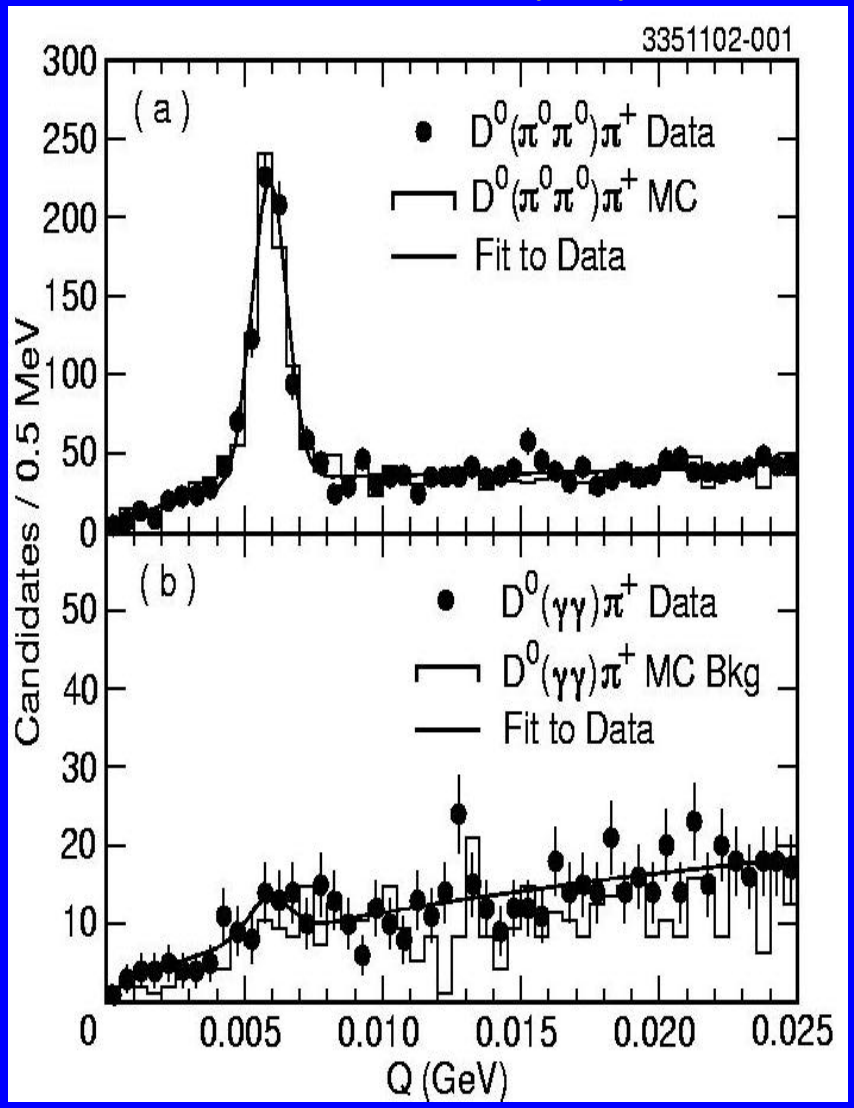
Use $D^{*+} \to D^0\pi^+$ tag

Normalize to $D^0 \to \pi^0\pi^0$

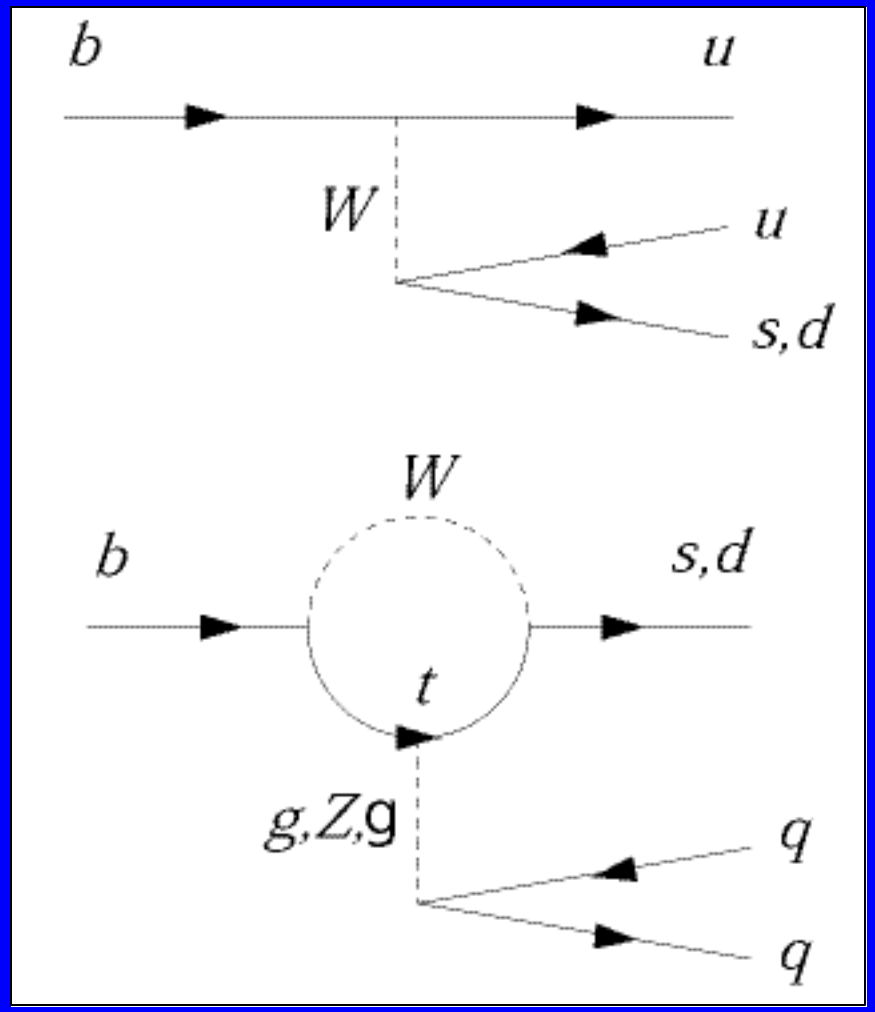
$$\frac{B(D^0 \to \gamma\gamma)}{B(D^0 \to \pi^0\pi^0)} < 0.033$$

$$B(D^0 \to \gamma\gamma) < 2.9 \times 10^{-5}$$

PRL 90, 101801 (2003)



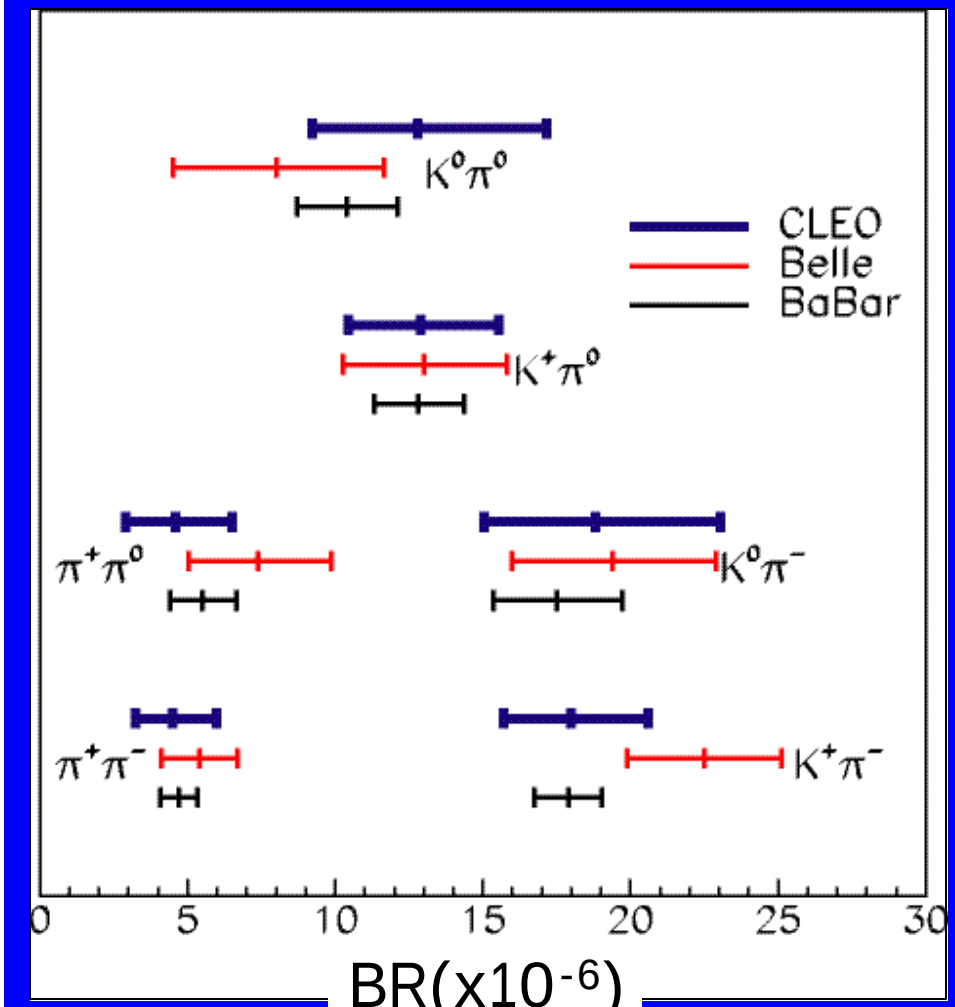
B→ππ,Kπ, DK: windows on γ



- B→ππ, Kπ can proceed via b→u (tree),
  - FCNC sensitive to new particles in loops
- or b→s, b→d (penguins)
  - Sensitive to |Vub| phase γ
- B→ππ,Kπ + theory gives γ
- Final results from CLEO Υ(4S) datasets: 15.3 fb^{-1} + 6.6 fb^{-1} below Υ(4S)

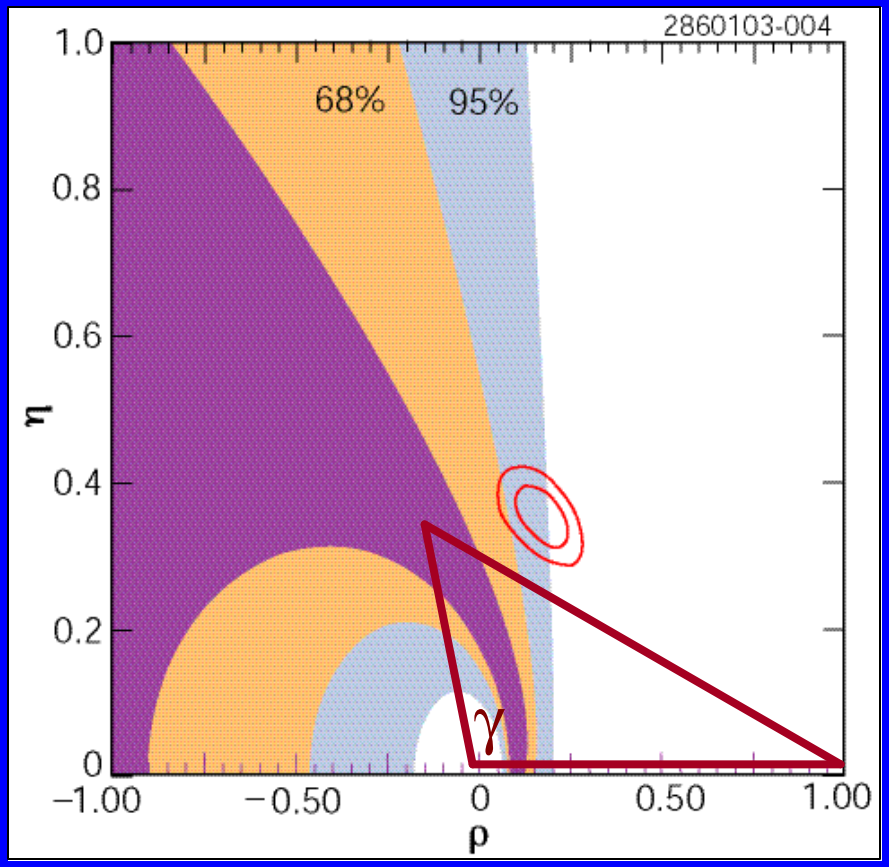
PRD 68, 052002 (2003)

CLEO Results B→ππ, Kπ



- Look at 13 modes
  - Kπ,ππ,KK,ΛΛ,pp,Λp
- Reconstruction
  - Suppress qq bkgd (shape)
  - PID for K with RICH
  - Peaks in ΔE and M(B)
  - Max. Likelihood fits
- 6 modes w/ significance
- KK limits at 10^{-6} level
- Good agreement with
  - Previous CLEO (II,II.V)
  - Belle and BaBar (Mar'03)
- CLEO Combined on left

Implications for γ



À la Neubert (hep-ph/0207327)

BBNS: PRL 83, 1914 (1999)
NPB 606, 245 (2001)

$$R^* = \frac{\mathbf{B}(B^\pm \to K^0 p^\pm)}{2\mathbf{B}(B^\pm \to K^\pm p^0)}$$

=0.71 ± 0.09 (WA Mar03)

$$e_{\exp} = \left|\frac{T}{P}\right| = \tan q_c \frac{f_K}{f_p}\left[\frac{2\mathrm{B}(B\to p^\pm p^0)}{\mathrm{B}(B\to K^0 p^\pm)}\right]^{1/2}$$

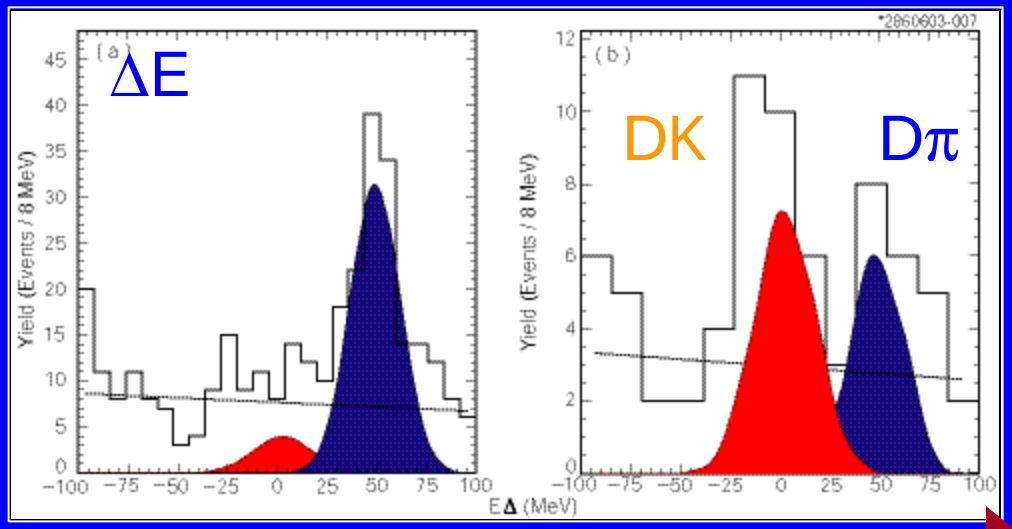
=0.21 ± 0.02 (WA Mar03)

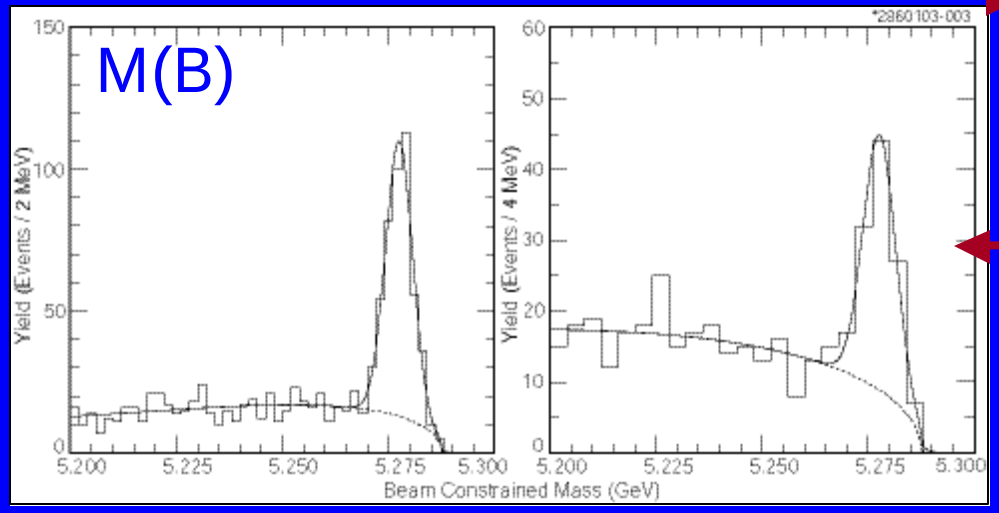
Exp+Theory: γ>90° ?

CLEO III $B^- \to D^0 K^-$

With PID Cuts

PRD 68, 052002 (2003)





- Can proceed via $b \to c\bar{u}s$ or $b \to u\bar{c}s$
- Interference via $(D/\bar{D}) \to f$ gives sensitivity to γ
- MLFit to CLEO III with RICH PID
- Projections of MLFit

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

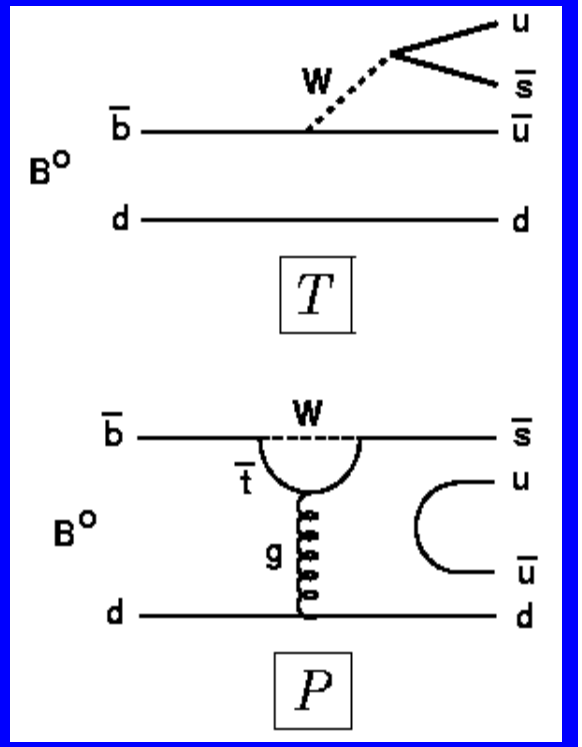
A_{CP} in the decay rate of $B^0 \to K^*(892)^+\pi^-$

- In SU(3) symmetry limit:

$$A(B^0 \to K^*(892)^+ p^-) = -|P| + |T| e^{i(g+d)}$$

$$\overline{A}(\overline{B}^0 \to K^*(892)^- p^+) = -|P| + |T| e^{i(-g+d)}$$

- Measuring $\langle B \rangle \sim (A^2 + \overline{A}^2)$ and $A_{CP} \sim \langle B \rangle (\overline{A}^2 - A^2)$ allows the extraction of both γ and the strong phase, δ.

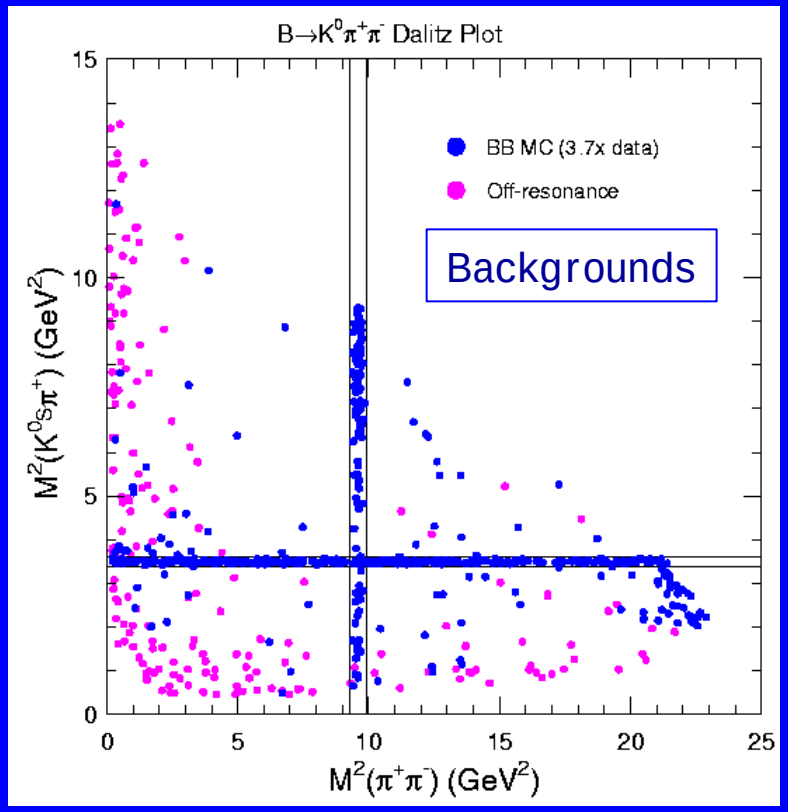


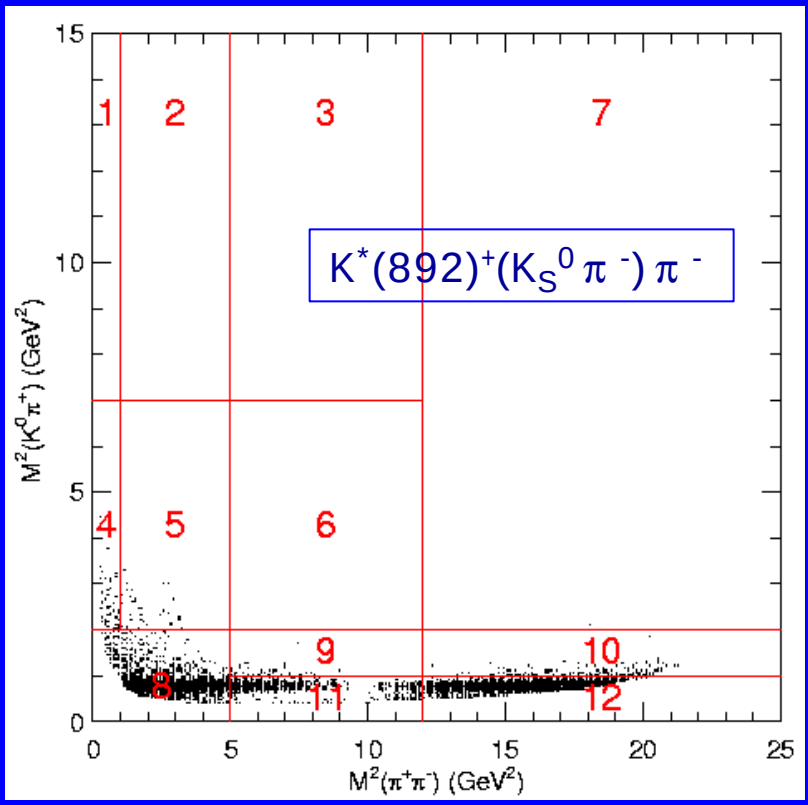
- CLEO measured (PRL 89, 251801 (2002)):

$$B(B \to K^*(892)^{\pm} p^{\mp}) = (16^{+6}_{-5} \pm 2) \times 10^{-6}$$

- This study extends the previous analysis and measures:

$$A_{CP} \equiv \frac{B(\overline{B}^0 \to K^*(892)^- p^+) - B(B^0 \to K^*(892)^+ p^-)}{B(\overline{B}^0 \to K^*(892)^- p^+) + B(B^0 \to K^*(892)^+ p^-)}$$

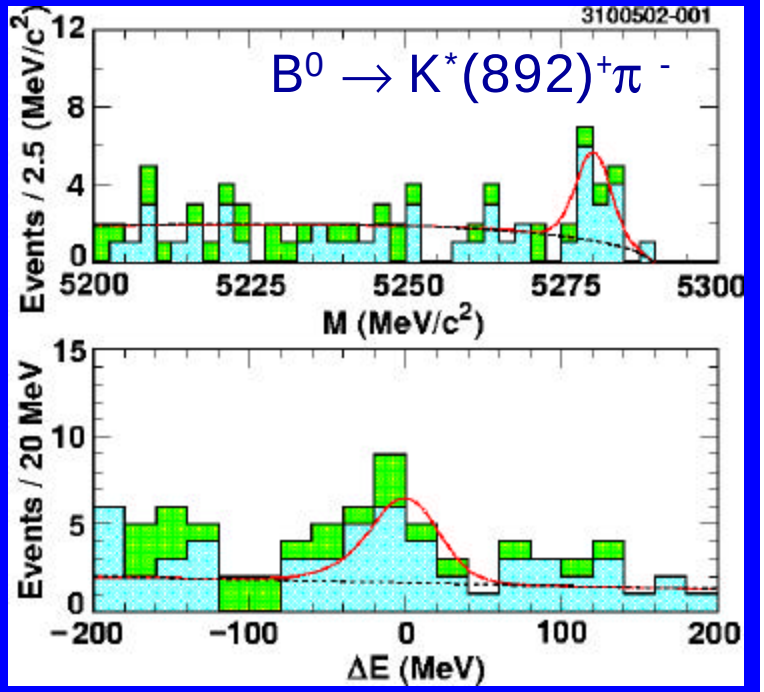




- Final state particles: $(K^+\pi^0)h^-$, $(K_S\pi^+)h^-$ where h= π^- or K^-
- Veto: B→Dπ; D→Kπ and B→J/ψK; J/ψ → μμ
- Simultaneous fit to Dalitz plots using a reasonable menu of resonances: K*(892), K*(1430), ρ(770), $f^0(980)$
- MLFit uses PDFs (M_B, ΔE, F, cos θ_B, PID, Dalitz M^2's) taken from MC and off-resonance data

Results for A_{CP} in $B^0 \to K^*(892)^+\pi^-$

- Fit results
  - Yield for $B^0 \to K^*(892)^+\pi^-$, $K^{*+} \to K_S^0\pi^+$: 12.6 ± 4
  - Yield for $B^0 \to K^*(892)^+\pi^-$, $K^{*+} \to K^+\pi^0$: 6.1 ± 2
  - Combined significance 4.6 s
- Systematic errors
  - Dalitz PDF shapes
  - Fitting method
  - Interference among intermediate resonances
  - Number of resonances in fit
- Final results for A_{CP} :



$$A_{CP}(B^0 \to K^*(892)^+ p^-) = 0.26^{+0.33\,+0.10}_{-0.34-0.08}$$

$$A_{CP}(B^0 \to K^*(892)^+ p^-) \in [-0.31; +0.78] \quad \text{at} \quad 90\%\,\text{C.L.}$$

PRD 68, 017101 (2003)

Analysis of results (CLEO+Belle) weakly favors $\cos\gamma < 0$ (W. Sun hep-ph/0307212)

More CLEO Physics

- Charmless B decays
  - B→ $\eta' X_s$ BF
  - Upper Limit on Baryons in B → $X_s\gamma$
- CKM physics
  - $|V_{cb}|$ and $|V_{ub}|$: Ron Poling's talk
- Charmed Baryons
  - CPV in $\Lambda_c \rightarrow \Lambda$ e ν
- Charm Decays
  - Branching fractions
  - Mixing and DCSD
  - Dalitz plot analyses
    - Hadronic structure
    - CPV via interference in Dalitz Plot $D^0 \rightarrow \pi^+\pi^-\pi^0$

Summary

- CLEO clearly sees two $c\bar{s}$ states
  - $D_{sJ}^*(2317) \rightarrow D_s \pi^0$
  - $D_{sJ}(2463) \rightarrow D_s^* \pi^0$
  - Other decays modes searched for & not seen
- CLEO searches for FCNC in charm decays
  - $D^0 \rightarrow \gamma\gamma$
- CLEO measures rare B decays with information on γ