Cabibo-suppressed D^+ Decays to $\pi^+\pi^0,\ K^0_S K^+,\ K^+\pi^0$

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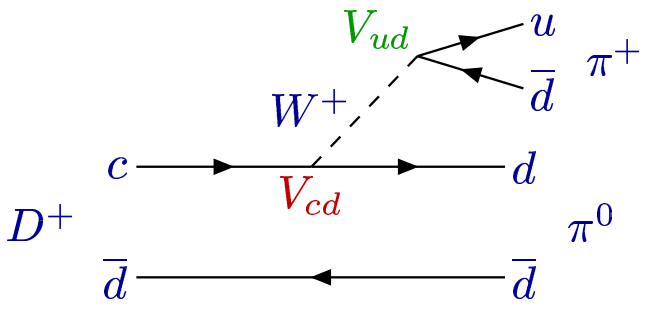
CLEO Plenary Talk

- Overview of Problem
- Description of Analysis Method
- Systematic Errors
- Preliminary Results
- Preliminary Upper Limit on $D^+ \to K^+\pi^0$
- SU(3) Symmetry Breaking for $\pi\pi$ and KK modes
- Conclusion

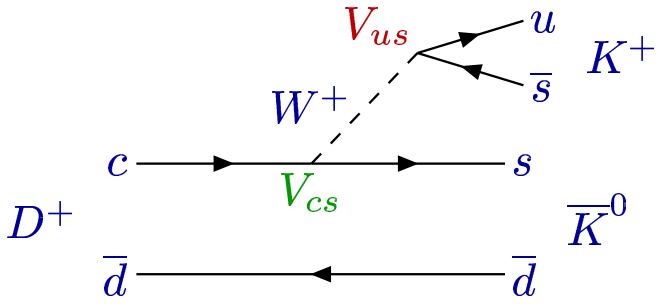
Overview of Problem

- Measure $D^+ \to \pi^+\pi^0$ (SCSD)



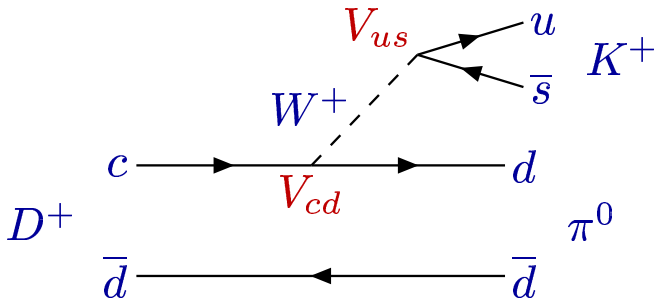
  - CLEO measurement (CBX 92-111): $BR(D^+ \to \pi^+\pi^0) = (2.5 \pm 0.6 \pm 0.5) \times 10^{-3}$
  - Significant for SU(3) symmetry breaking

- Also measure $D^+ \to K^+\overline{K}^0$ (SCSD)



  - CLEO measurement (CLNS 96/1449): $\frac{BR(D^+ \to K^+ K_S)}{BR(D^+ \to \pi^+ K_S)} = (2.2 \pm 4.1 \pm 1.9)\%$
  - PRL 88 p041602 (FOCUS - 2002): $\frac{BR(D^+ \to K^+ \overline{K}^0)}{BR(D^+ \to \pi^+ \overline{K}^0)} = (19.96 \pm 1.19 \pm 0.96)\%$
  - Also significant for SU(3) symmetry breaking

- Attempt to measure $D^+ \to K^+\pi^0$ (DCSD)



  - Theory predicts Branching Fraction on the order of 10^{-4}
  - There are currently no limits that have been published
  - $BR(D^0 \to K^+\pi^-) = (1.48 \pm 0.21) \times 10^{-4}$; $\frac{\tau_{D^+}}{\tau_{D^0}} = 2.55 \Rightarrow 3.77 \times 10^{-4}$

Description of Analysis

Analysis Strategy:

- Use CLEO II and I.V data sets
- Look for $D^{*+} \to D^+\pi^0 \Rightarrow D^+ \to K^+\pi^0, \pi^+\pi^0, K_sK^+$
- Use normalization modes to reduce systematics:
  - $D^+ \to K^-\pi^+\pi^+$ for $K^+\pi^0, \pi^+\pi^0$
  - $D^+ \to K_s\pi^+$ for K_sK^+
- Use Likelihood Fitter (FELIX) to extract yields from data

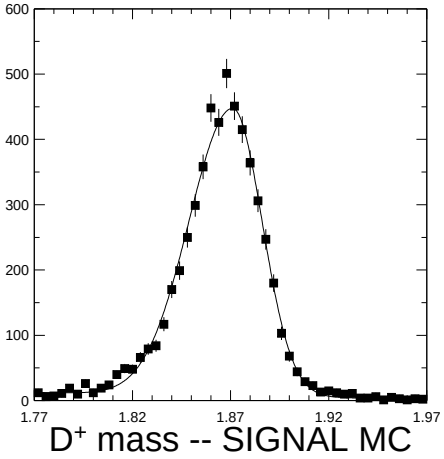
Fit Variable Determination:

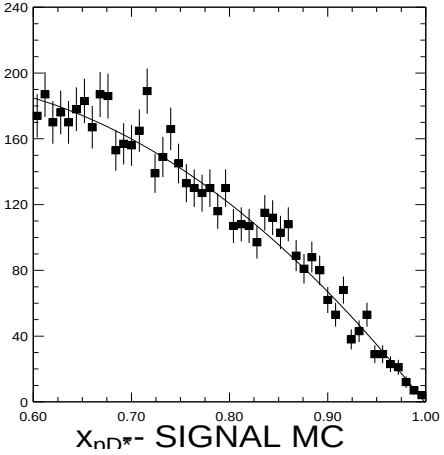
- Need to choose variables to use in FELIX
- Use variables with differing shapes for signal and background
  - D^+ mass, x_{pD*}, and cos $\theta_{helicity}$
- Define Preselection Cuts on the fit variables:
  - 5 σ on D^+ mass
  - $x_{p_{D*}} > 0.6$
  - $|cos\theta_{helicity}| < 0.8$

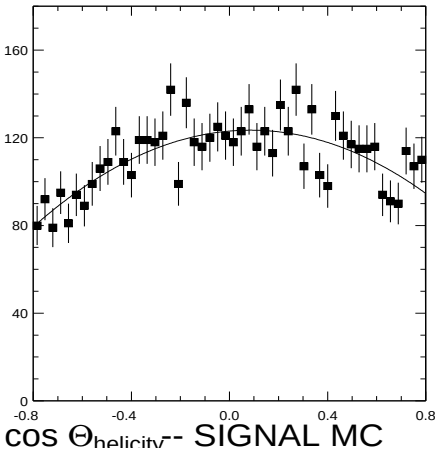
Define Cuts:

- Define track cuts:
  - $TRACKMAN \geq 0$
  - $KINCD \geq 0$
  - No z-escape or dredge tracks
  - $|DBKL| < 0.005$
  - $|Z0KL| < 0.05$
  - $p_{track} > 100MeV$
- Particle ID:
  - $|SGKADI(K^{\pm})| < 2.0$
  - $|SGPIDI(\pi^{\pm})| < 3.0$
- CCFC π^0 selection:
  - $m(\gamma\gamma)$ must be within 2.5σ of nominal π^0 mass
  - $E9/E25$ cut at the 99% level
  - χ^2 on the kinematic fit of the $\gamma - \gamma$ pair had to be greater than 0 and less than 10
- K_s selection:
  - K_s from KNVF package
  - Use only "gold-plated" candidates (KINCD = 2)
- Use D^* tag with slow π^0
  - 2.5 σ cut on $m(D^{*+}) - m(D^+)$

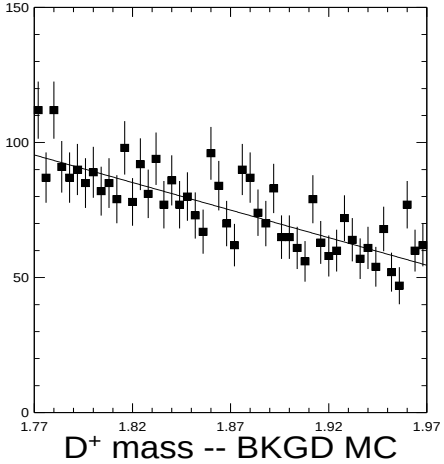
- Create PDFs which describe the signal and background shapes for each mode:
  - Signal: D^+ mass, $x_{p_{D^*}}$, $cos\theta_{helicity}$ for $D^+ \to \pi^+\pi^0$

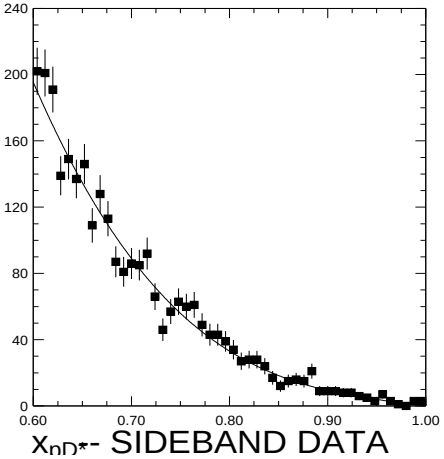


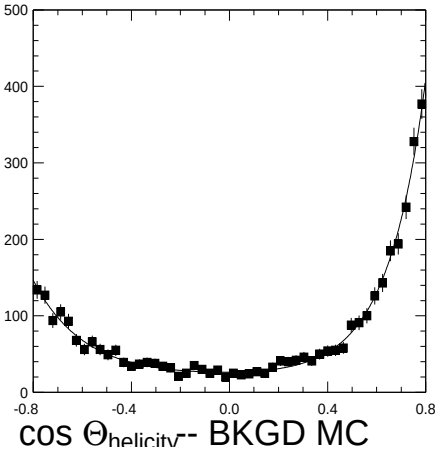




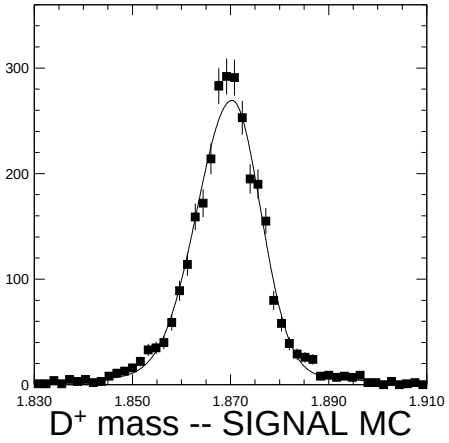
  - Corresponding Background:

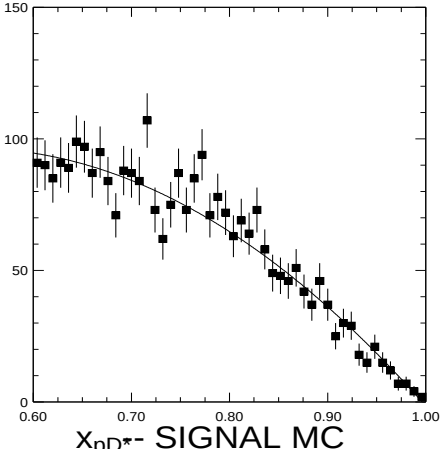


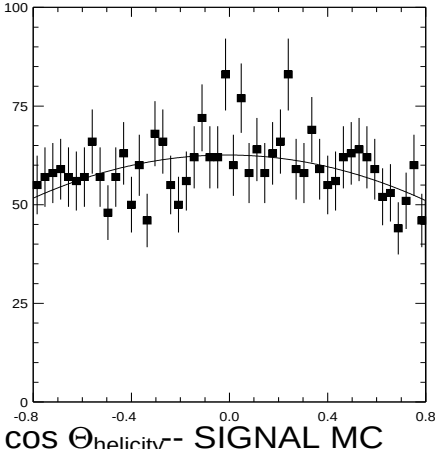




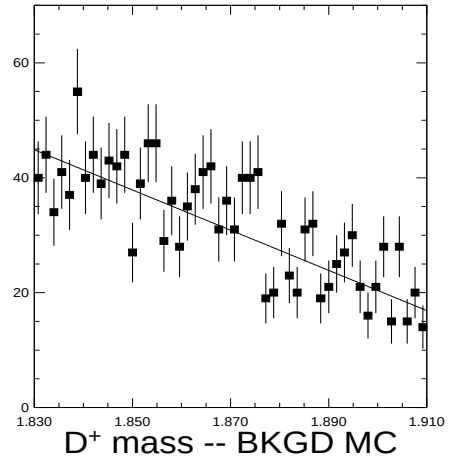
– Signal: D^+ mass, $x_{p_{D^*}}$, $cos\theta_{helicity}$ for $D^+ \to K^+K_S$

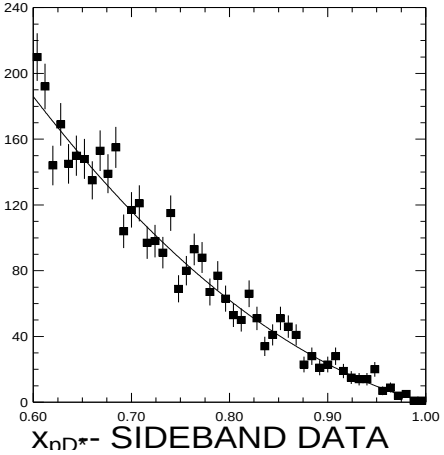


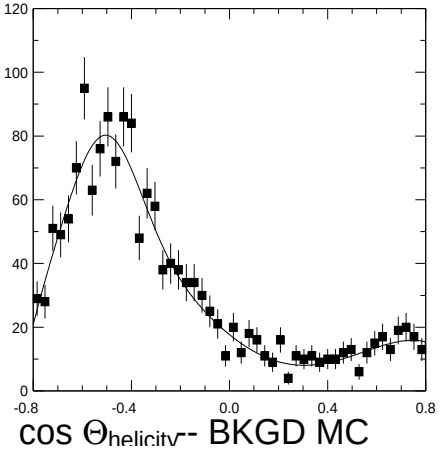




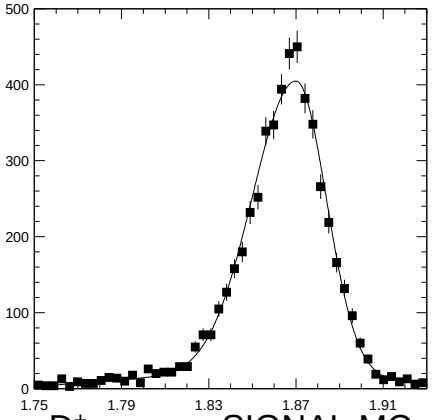
– Corresponding Background:

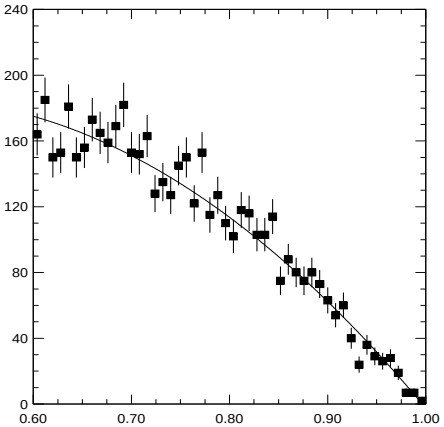


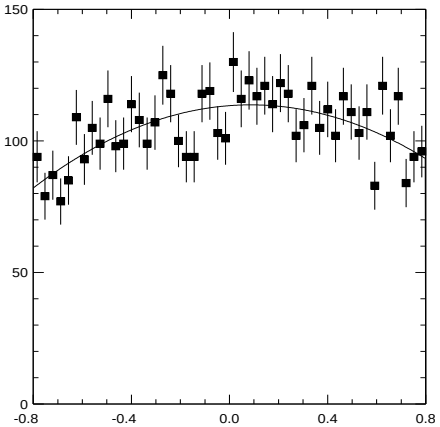




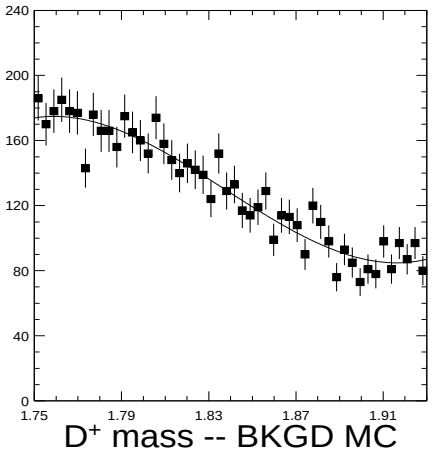
- Signal: D^+ mass, $x_{p_{D^*}}$, $cos\theta_{helicity}$ for $D^+ \to K^+\pi^0$

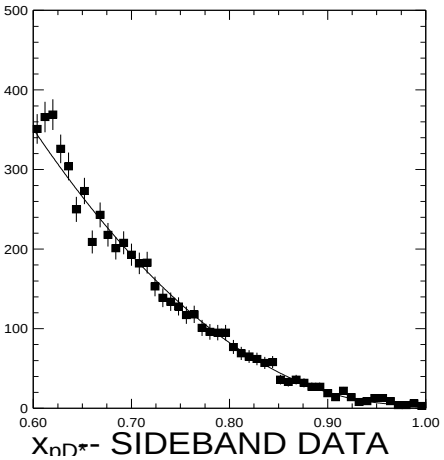


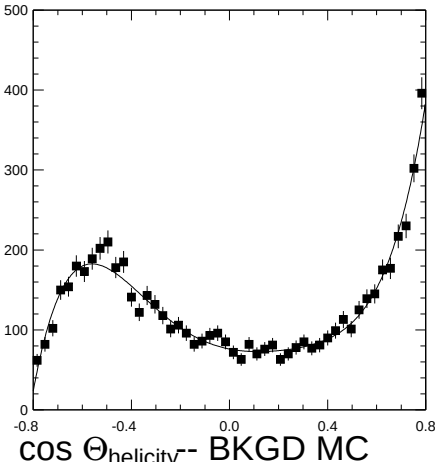




- Corresponding Background:

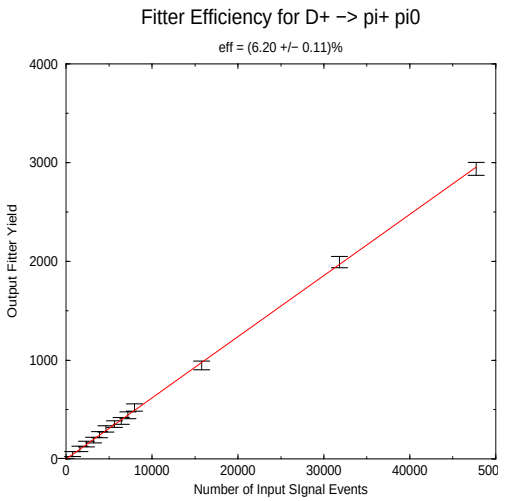


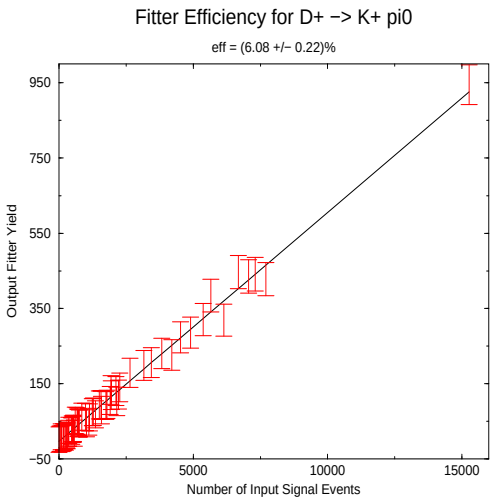


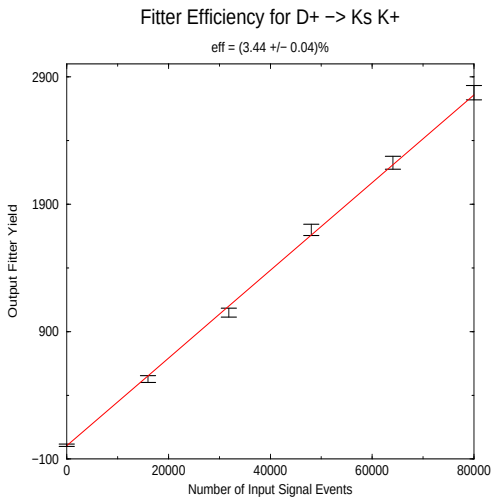


- Calculate Efficiencies for Fitter using Generic MC from staged tapes:
  - Create samples of varying amounts of events from signal MC
  - Corrected generic background MC $x_{p_{D^*}}$
  - Combined each signal MC sample with the corrected background MC and fit
  - Plot fit yields to a line to obtain efficiency
  - Resulting Efficiencies for Each Mode:

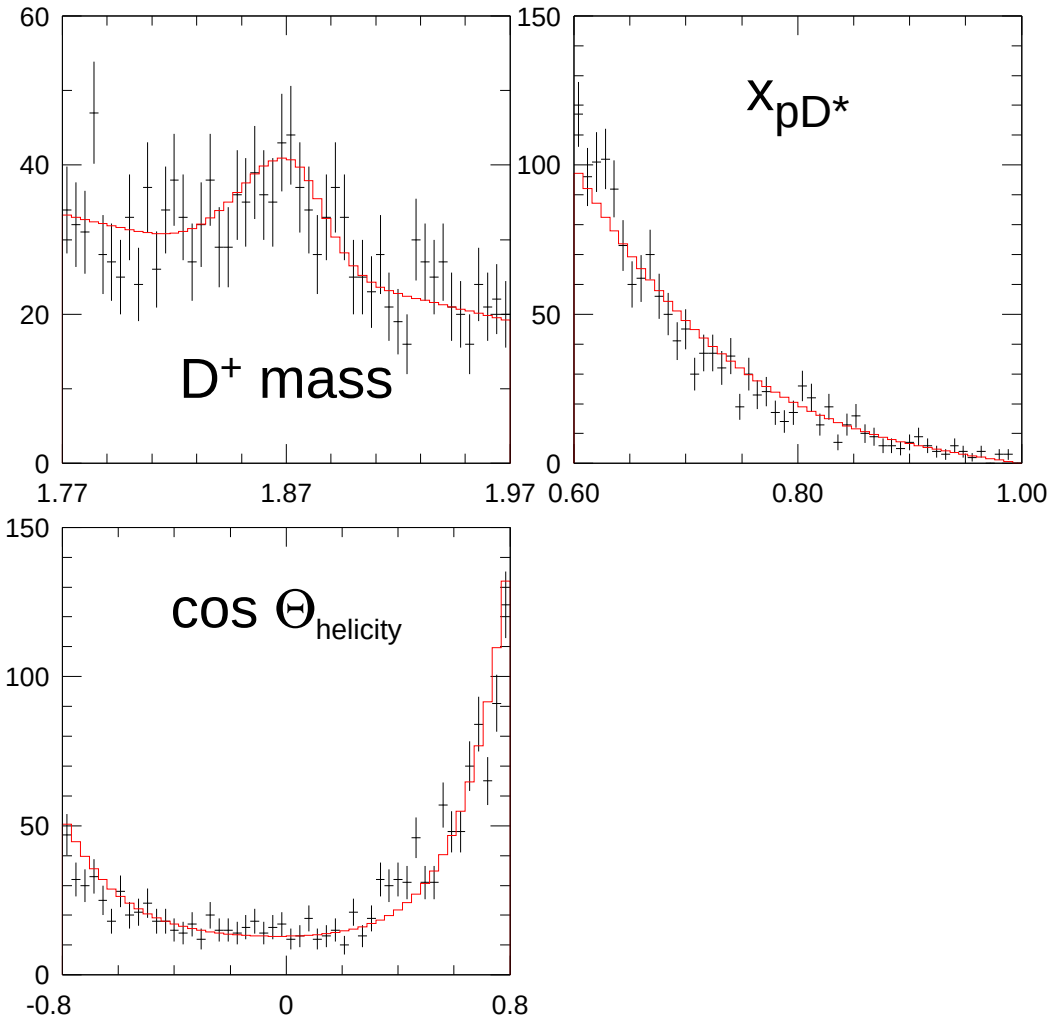
Mode	Efficiency	Offset
$\pi^+\pi^0$	$(6.20 \pm 0.11)\%$	-2.87 ± 10.21
$K^+\pi^0$	$(6.08 \pm 0.22)\%$	-2.87 ± 6.43
K^+K_s	$(3.44 \pm 0.04)\%$	4.26 ± 8.66



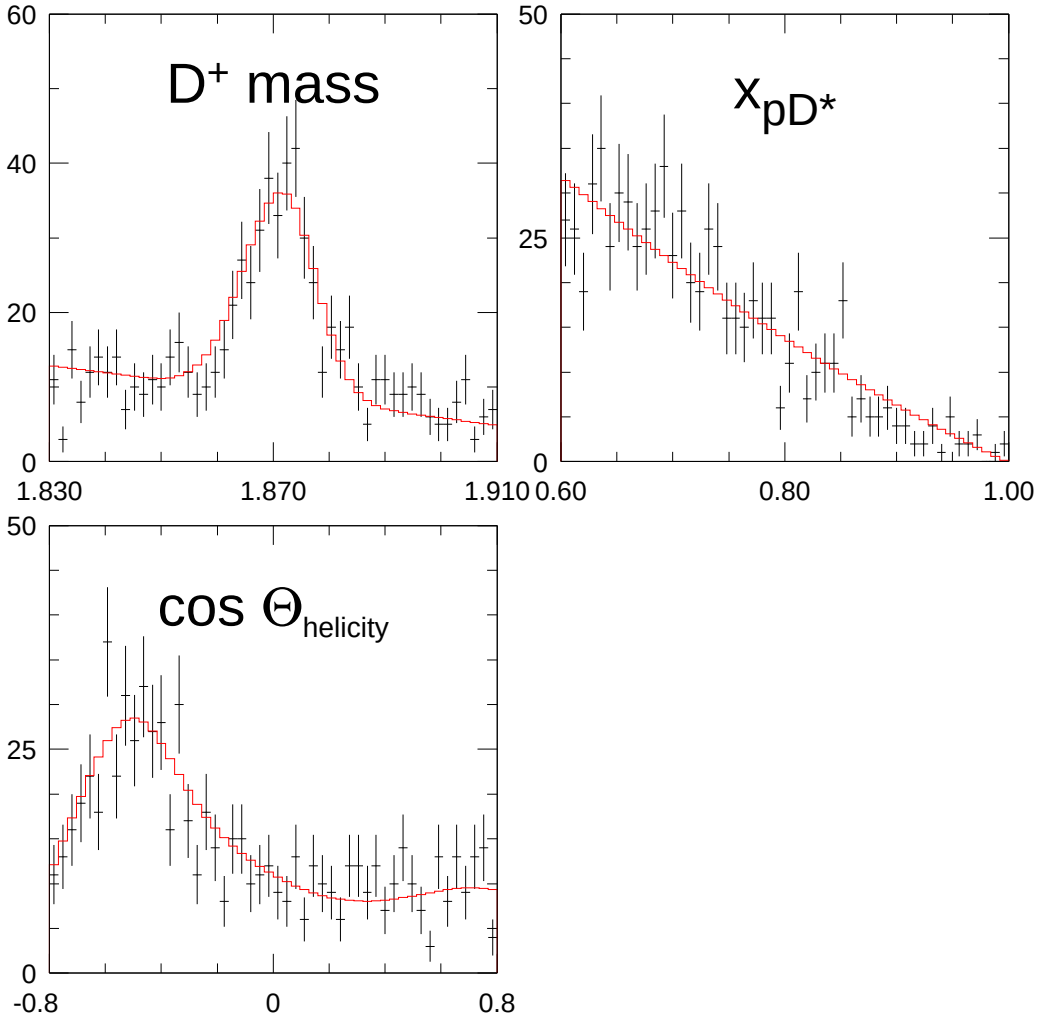




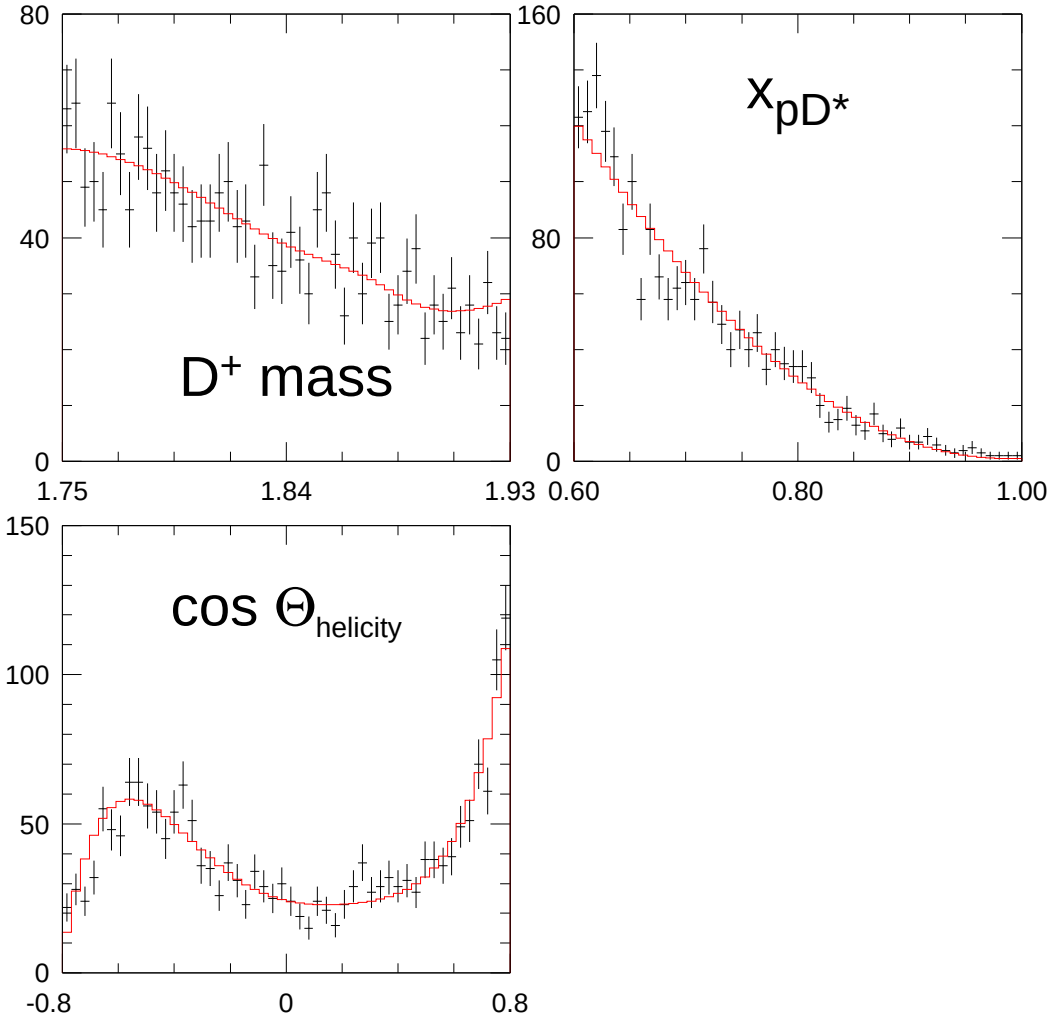
- Run on Data:
  - Yield for $D^+ \to \pi^+\pi^0 = 171.32 \pm 2.07$



– Yield for $D^+ \to K^+ K_s = 277.70 \pm 20.76$

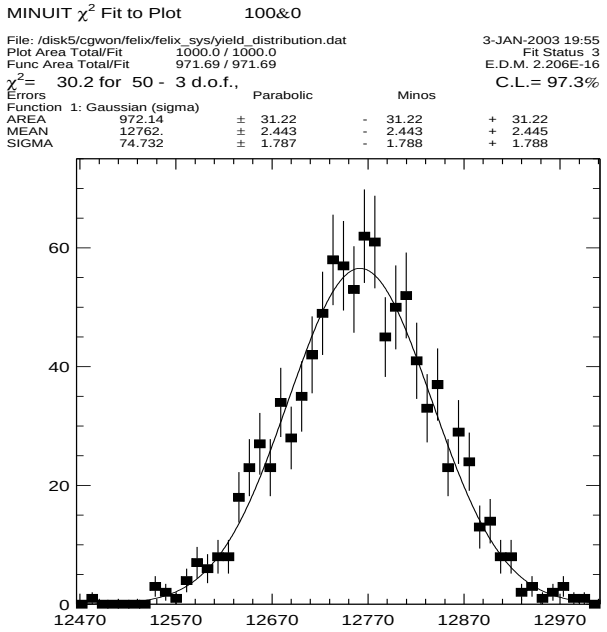


– Yield for $D^+ \to K^+\pi^0 = 34.31 \pm 20.88$



Systematic Errors

- 2% from charged tracks (1 charged track in signal mode, 3 in normalization)
- 3% from π^0 reconstruction
- 1.0 - 2.2% from error on efficiency calculation
- PDF systematics:
  - Modify all PDFs simultaneously using MINOS errors from shapes
  - Fit data with new PDF definitions
  - Repeat 1000 times and create distribution of yields from fitter
  - Calculated 68% limits for each distribution of yields
  - Sys Error on $D^+ \to K^-\pi^+\pi^+ = \pm 74.73$ (0.54%) :



– Resulting Systematic Errors:

Decay Mode	Mean + Stat Error	Systematic Error
$\pi^+\pi^0$	171.32 ± 22.07	± 8.09
$K^+\pi^0$	34.31 ± 20.88	± 10.66
K^+K_s	277.70 ± 20.76	± 7.100
$K^-\pi^+\pi^+$	13856 ± 152.25	± 74.73
π^+K_s	1470.1 ± 47.53	± 41.61

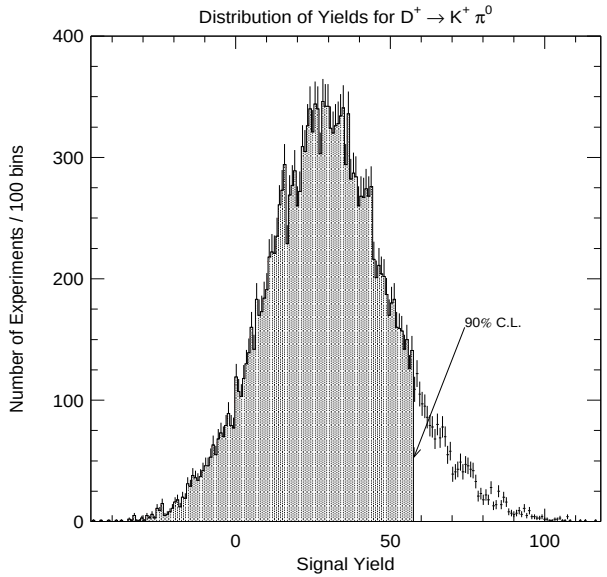
*

Preliminary Results

- $D^+ \to \pi^+\pi^0$:
  - $\frac{BR(D^+\to\pi^+\pi^0)}{BR(D^+\to K^-\pi^+\pi^+)} = (1.44 \pm 0.19 \pm 0.09)\%$
  - $BR(D^+ \to \pi^+\pi^0) = (1.31 \pm 0.2 \pm 0.1) \times 10^{-3}$
  - CLEO 1992: $BR(D^+ \to \pi^+\pi^0) = (2.5 \pm 0.6 \pm 0.5) \times 10^{-3}$
  - Our studies using only 4s2 and 4s3 have agreed with the previously published result
- $D^+ \to K^+\overline{K}^0$:
  - $\frac{BR(D^+\to K^+K_s)}{BR(D^+\to\pi^+K_s)} = (18.74 \pm 1.53 \pm 0.85)\%$
  - CLEO 1996: $\frac{BR(D^+\to K^+K_S)}{BR(D^+\to\pi^+K_S)} = (2.2 \pm 4.1 \pm 1.9)\%$
  - FOCUS 2002: $\frac{BR(D^+\to K^+K_S)}{BR(D^+\to\pi^+K_S)} = (19.96 \pm 1.19 \pm 0.96)\%$
- $D^+ \to K^+\pi^0$:
  - $\frac{BR(D^+\to K^+\pi^0)}{BR(D^+\to K^-\pi^+\pi^+)} = (2.9 \pm 1.8 \pm 0.9) \times 10^{-3}$
  - $BR(D^+ \to K^+\pi^0) = (2.6 \pm 1.6 \pm 0.8) \times 10^{-4}$
  - $BR(D^0 \to K^+\pi^-) \times \frac{\tau_{D^+}}{\tau_{D^0}} = 3.77 \times 10^{-4}$
  - Need to calculate upper limit

Preliminary Upper Limit on $D^+ \to K^+\pi^0$

- Confirmed that Correlations were not significant between fit parameters
- Created 500 new "datasets" using Signal and Background Yields from FELIX:
  - Created 34 "Signal Events" by generating random numbers for each fit variable as defined by the signal PDF shapes
  - Created 1711 "Background Events" by generating random numbers for each fit variable as defined by background PDF shapes
- Varied each PDF systematicaly 40 times, refitting with each variation
- Created histogram from all resulting yields
- $\frac{D^+ \to K^+\pi^0}{D^+ \to K^-\pi^+\pi^+} < 0.0046 \Rightarrow BR(D^+ \to K^+\pi^0) < 4.2 \times 10^{-4}$ @ 90% C.L.



SU(3) Symmetry Breaking

To study SU(3) symmetry breaking, need results from $D^0 \to \pi\pi(KK)$ as well as $D^+ \to \pi\pi(KK)$

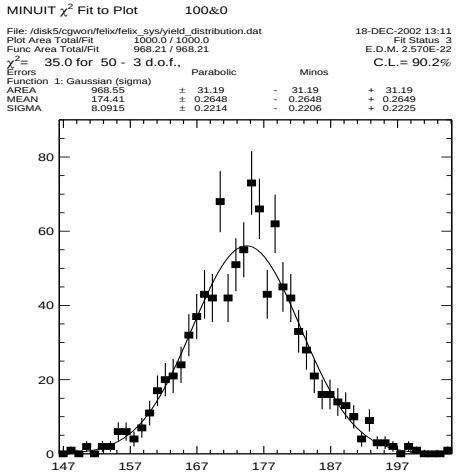
- For $D^+ \to \pi^+\pi^0$:
  - CBX 92-111 gave the following results:
    - $\left|\frac{A_2}{A_0}\right| = 0.72 \pm 0.17$
    - $cos\delta = 0.14 \pm 0.16 \Rightarrow \delta = 81.95$
  - Our results:
    - $\left|\frac{A_2}{A_0}\right| = 0.42 \pm 0.04$
    - $cos\delta = 0.04 \pm 0.19 \Rightarrow \delta = 87.71$
- For $D^+ \to K_s K^+$:
  - CLNS 96/1449 gave the following results:
    - $\left|\frac{A_1}{A_0}\right| = 0.61^{+0.11}_{-0.10}$
    - $cos\delta = 0.88^{+0.10}_{-0.08} \Rightarrow \delta = 28.36$
  - Our results:
    - $\left|\frac{A_1}{A_0}\right| = 0.52 \pm 0.03$
    - $cos\delta = 0.87 \pm 0.08 \Rightarrow \delta = 29.54$

Conclusion

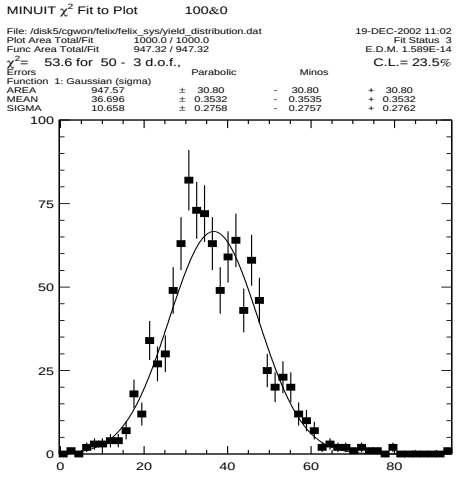
- ALL results are still preliminary!
- $\frac{BR(D^+ \to \pi^+\pi^0)}{BR(D^+ \to K^-\pi^+\pi^+)} = (1.44 \pm 0.19 \pm 0.09)\%$ inconsistent with CLEO 93 result
- $\frac{BR(D^+ \to K^+K_s)}{BR(D^+ \to \pi^+K_s)} = (18.74 \pm 1.53 \pm 0.85)\%$ consistent with CLEO 97 and FOCUS 02 results
- $BR(D^+ \to K^+\pi^0) < 4.2 \times 10^{-4}$ @ 90% C.L. consistent with theoretical predictions

Extra Slides

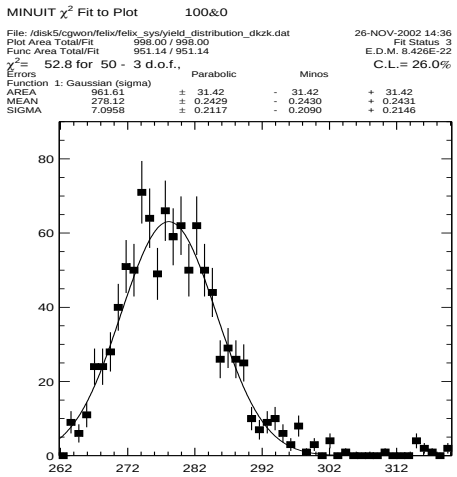
- Systematic Error on $D^+ \to \pi^+\pi^0 = \pm 8.09$ (4.7%):



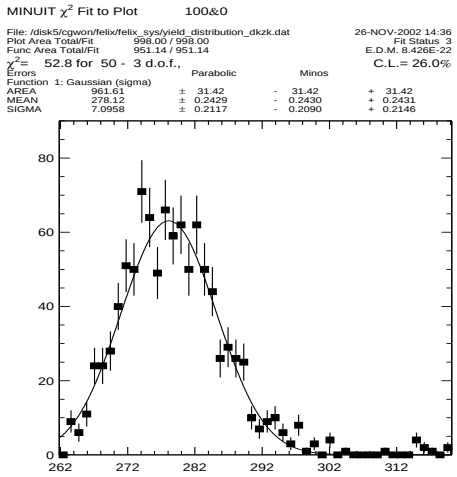
- Sys Error on $D^+ \to K^+\pi^0 = \pm 10.66$ (31.07%) :



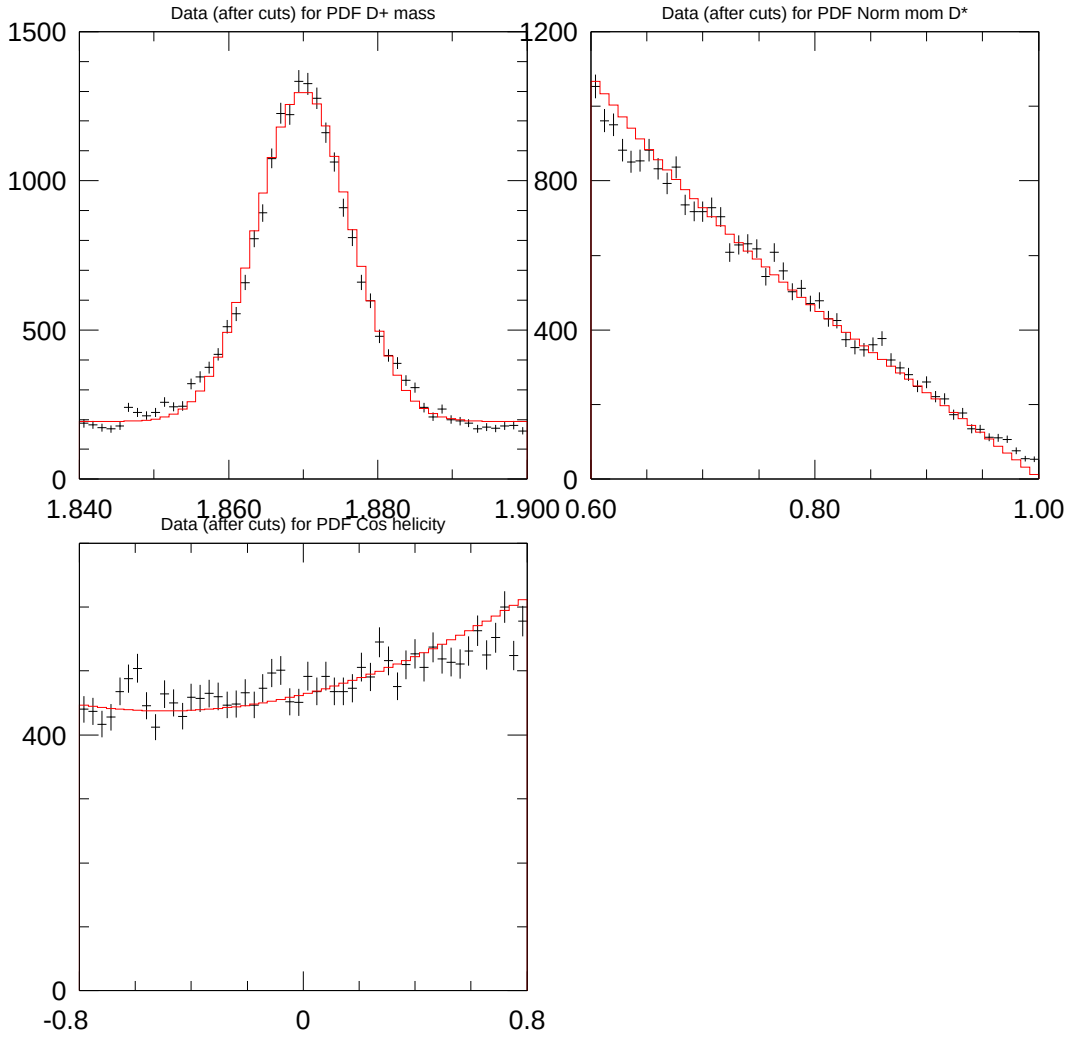
- Systematic Error on $D^+ \to K^+ K_s = \pm$ 7.10 (2.6%)



- Systematic Error on $D^+ \to \pi^+ K_s = \pm$ 41.61 (2.8%)



- Yield for $D^+ \to K^-\pi^+\pi^+ = 12898 \pm 157$



- Yield for $D^+ \to K_s\pi^+ = 1434.7 \pm 48.0$