CLEO-c: Recent Results

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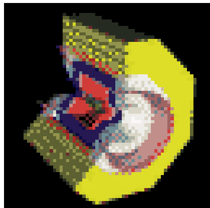
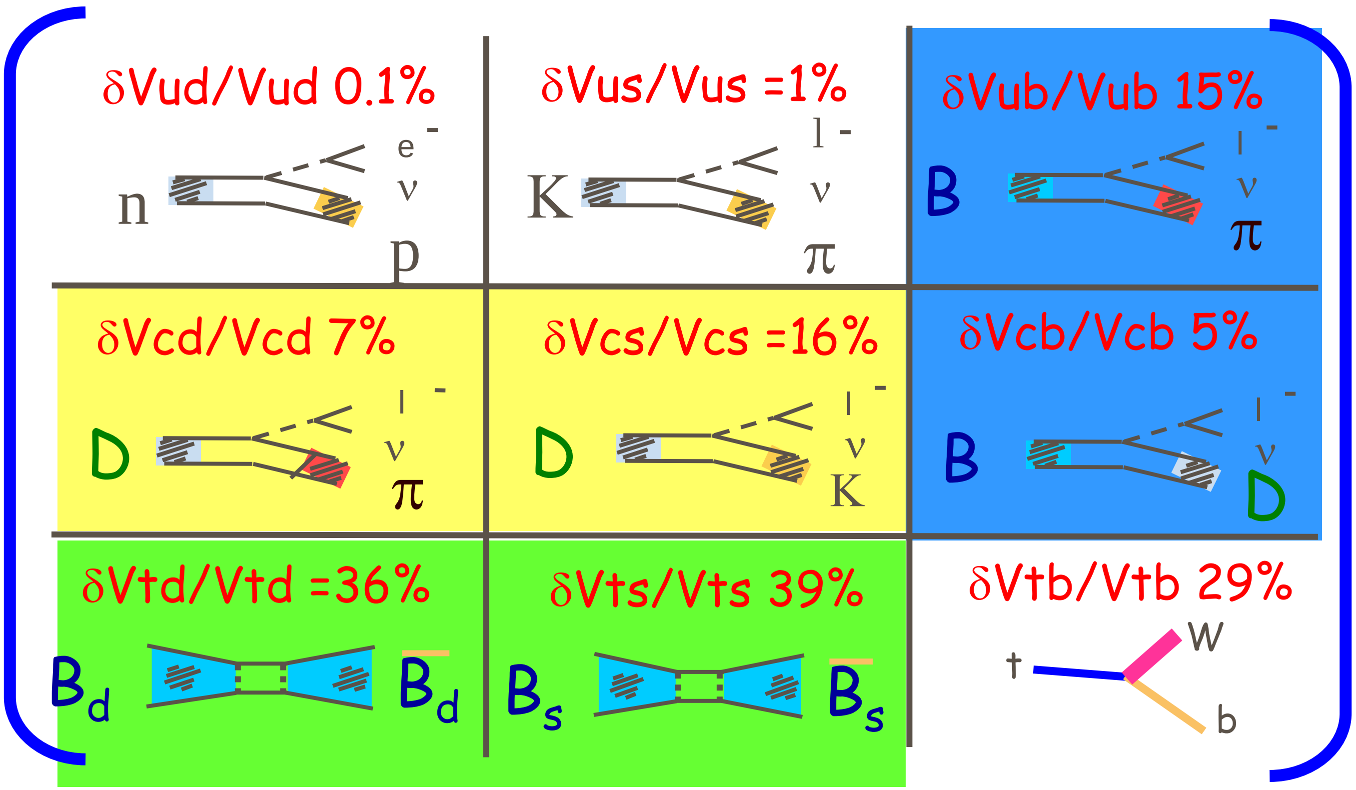
March 12, 2006
Moriond EW



Outline

- Program Overview
  - CLEOIII Result
- CLEO-c
  - Leptonic
  - Semileptonic
  - Hadronic

Impact of Physics

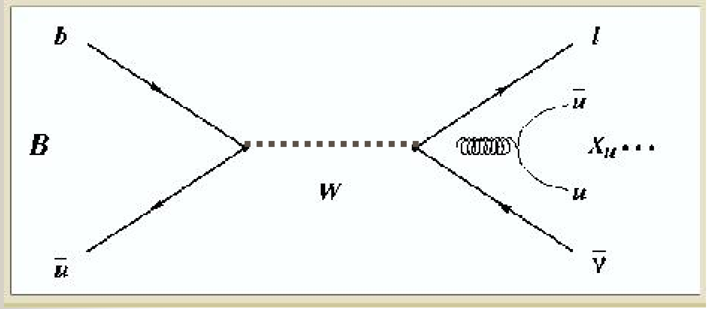


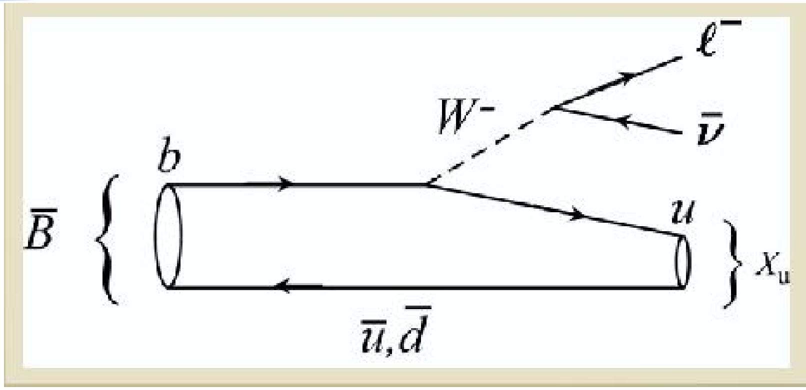
CLEO-c

CLEO-c + Lattice QCD +B factories

CLEO-c + Lattice QCD +B factories + ppbar

Weak Annihilation $B \rightarrow l\nu(X)$





*Annihilation of valence quarks (leptonic).

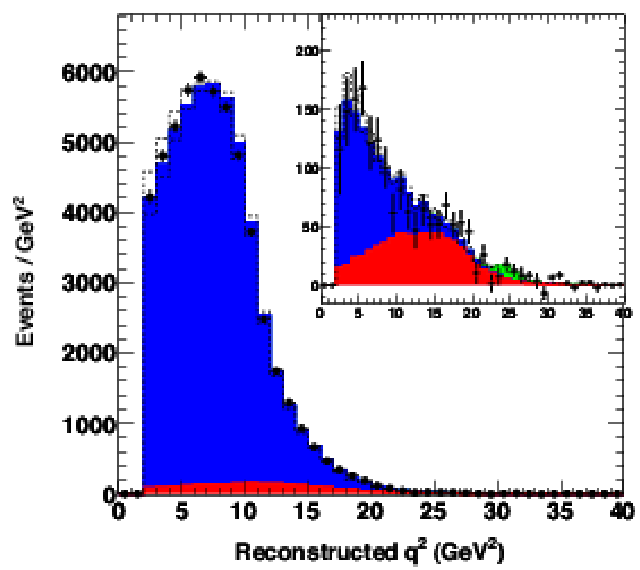
*Hadronization of residual "brown muck".

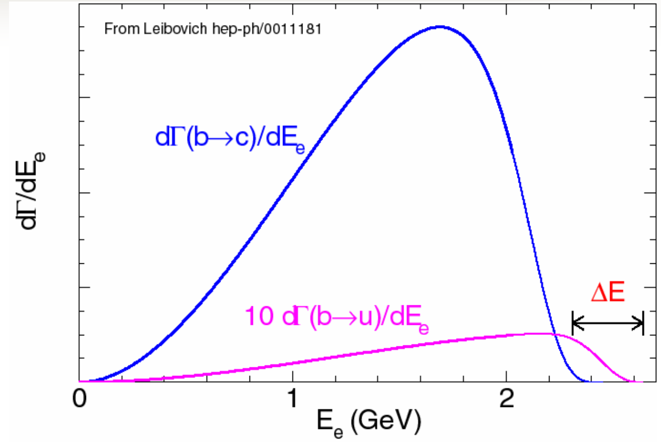
*Estimates of rate suggest small contribution from these these processes. (Order ~ $1/m_H^3$)

*However rate can be concentrated at high q^2.

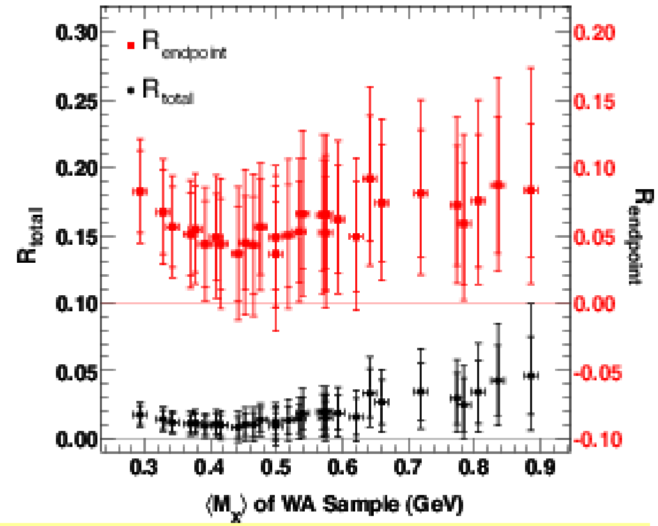
$$\Gamma_{WA}/\Gamma_{btou} \approx 0.03 \left(\frac{f_B}{0.2\ \text{GeV}}\right)^2 \left(\frac{B_2 - B_1}{0.1}\right)$$

WA: CLEOIII





R endpoint< 15.5%



$$R_a \equiv \frac{\Gamma_{WA}}{\Gamma_{btou}} = \frac{\Gamma_{WA}}{\Gamma'_{btou} + \Gamma_{WA}}$$

from fit

First direct experimental limits on a localized WA contribution.

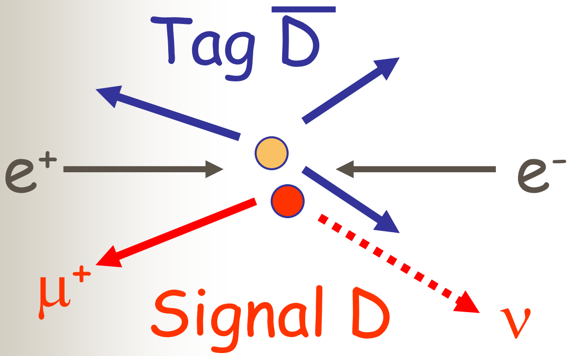
Submitted to PRL

CLEO-c Expected Datasets

- $\psi(3770)$
  - 1000/pb
  - 2 Million tagged D mesons
  - 100 times MARKIII
- $\sqrt{s}$ = 4170 MeV
  - 1000/pb
  - ~0.1 Million tagged Ds mesons
  - Scan completed.
- $\psi(3686)$
  - 30 million $\psi(3686)$

D-Tagging

D-Tagging



→Event Shape discrimination no longer a powerful powerful tool in the charm region.

→Backgrounds at $\psi(3770)$: continuum (18 nb), τ pair (3 nb), radiative return (~1.5 nb)

→D meson has large branchings to low multiplicity modes.

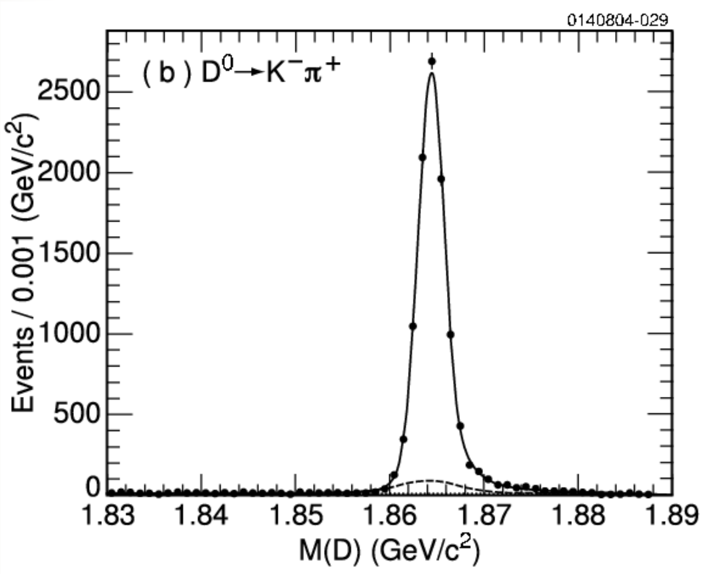
→Requiring a reconstructed D provides background suppression.

→D-Tagging removes half the event (only a single D remains).

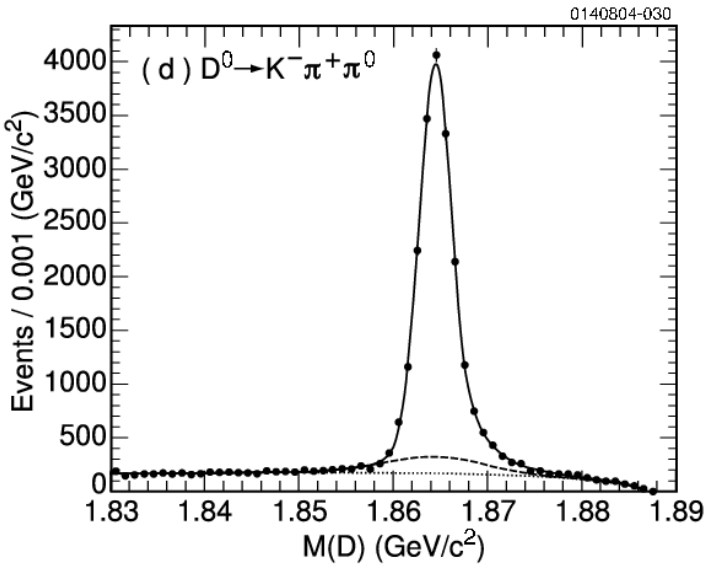
→Simultaneously provides 4-vector of other D meson.

D-Tagging

$D^0 \to K^- \pi^+$



$D^0 \to K^- \pi^+ \pi^0$

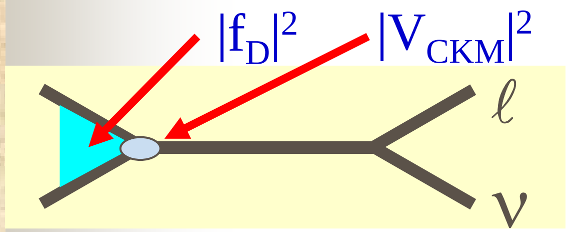


$$M_{bc} = \sqrt{E_{beam}^2 - P_{candidate}^2}$$

$$\Delta E = E_{beam} - E_{candidate}$$

Weak Annihilation: $D^+ \rightarrow \mu^+ \nu_\mu$

$$\Gamma(D_q^+ \rightarrow l\,\upsilon) = \frac{1}{8\pi} G_F^2 M_{D_q^+} m_l^2 \left(1 - \frac{m_l^2}{M_{D+}^2}\right) f_{D+}^2 |V_{cq}|^2$$

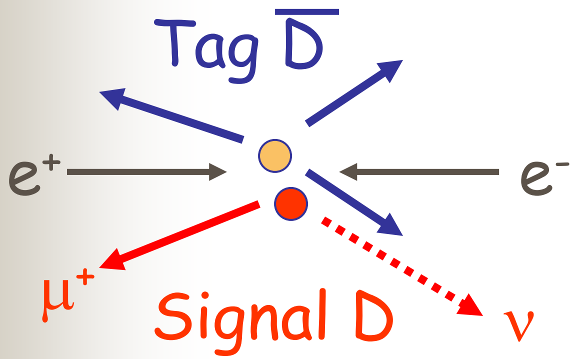


$$\Delta M_d = 0.50\,ps^{-1}\left[\frac{\sqrt{B_{B_d}}\,f_{B_d}}{200MeV}\right]^2\left[\frac{|V_{td}|}{8.8\times10^{-3}}\right]^2$$

Improvement in mixing constraints with better f_B
Ideally one would measure $B^+ \rightarrow l^+ \nu$ (rate too low).
Realistic alternative: Measure f_D,f_{Ds}.

$f_{D\ CLEO-c}$ and $(f_B/f_D)_{lattice} \rightarrow f_B$
(And f_D/f_{Ds} checks f_B/f_{Bs})

$D^+ \to \mu^+ \nu_\mu$



→One D fully reconstructed:
reconstructed:

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

$$D^- \to K^+\pi^-\pi^-\pi^0$$

$$D^- \to \overline{K}^0_S\pi^-$$

$$D^- \to \overline{K}^0_S\pi^-\pi^-\pi^+$$

$$D^- \to \overline{K}^0_S\pi^-\pi^0$$

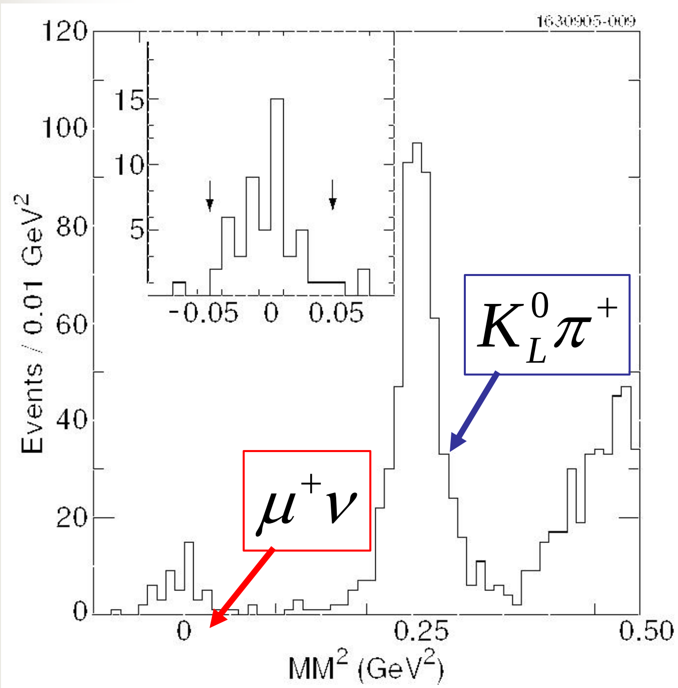
→Require single track on other side: μ

- PID suppresses K
- Calorimeter suppresses π^+
- Require low energy in CC

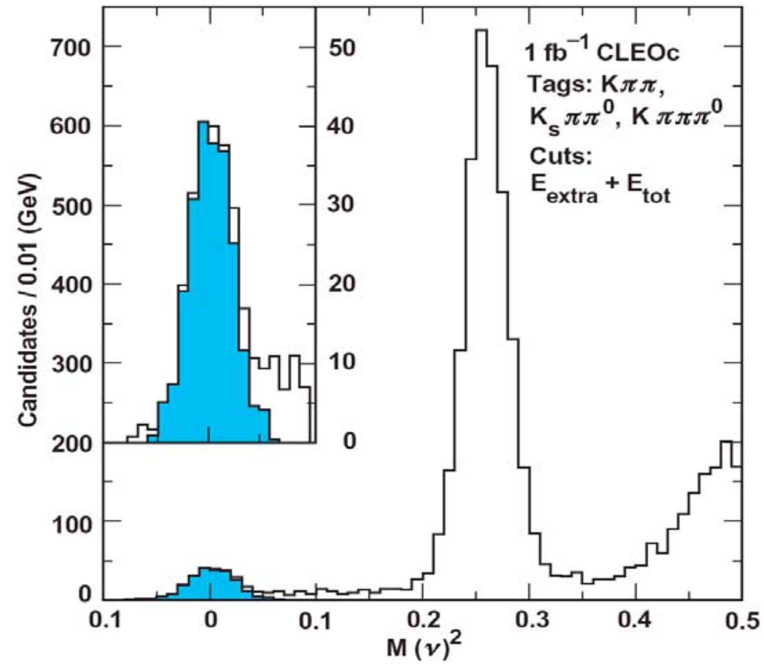
Use D 4-vector to calculate missing mass (~0 for ν).

$D^+ \to \mu^+ \nu_\mu$

Data (281 pb^{-1})



Monte Carlo (1 fb^{-1})



Mode	Events
Data	50
$D^+ \to \pi^+ \pi^0$	1.4
$D^+ \to K_{long} \pi^+$	0.33
$D^+ \to \tau^+ \nu_\tau$	1.08
Total Bck:	2.81

$$B(D^+ \to \mu^+ \upsilon) = (4.40 \pm 0.66^{+0.09}_{-0.12}) \times 10^{-4}$$

CLEO-c

$$f_{D^+} = (222.6 \pm 16.7^{+2.8}_{-3.4}) MeV$$

PRL 95 251801 (2005)

Lattice

$$f_{D^+} = (201 \pm 3 \pm 17) MeV$$

PRL 95 122002 (2005)

$D^+ \rightarrow \tau^+ \nu_\tau \ (\tau \rightarrow \pi\nu)$

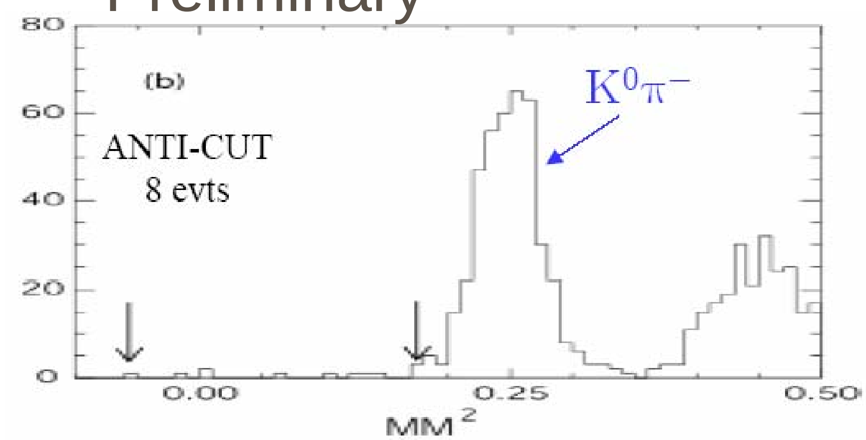
Data (281 pb^{-1})

$$\frac{\Gamma(D^+ \to \tau^+\nu)}{\Gamma(D^+ \to \mu^+\nu)} \neq \frac{m_\tau^2\left(1-m_\tau^2/M_D^2\right)^2}{m_\mu^2\left(1-m_\mu^2/M_D^2\right)^2}$$

$$R = \frac{\Gamma_{Measured}(D^+ \to \tau^+\nu)}{\Gamma_{SM}(D^+ \to \tau^+\nu)}$$

R<1.6 @90%

Preliminary



Anti-cut analysis vetoes
CC energy associated with track
That is consistent with muon.

Exclusive Semileptonic Decays

Motivation

→Direct access to CKM elements (V_{cs},V_{cd})

→High resolution measurement of q^2 spectrum. Confronts form factor predictions. ➔ Better extraction of V_{xb} from exclusive semileptonic B decays.

→ Opportunity for first observations.

Exclusive Semileptonic Decays

Technique

→D-Tag event
→Identify electron
→Reconstruct the hadronic component
→Check for consistency with neutrino
$U=E_{miss}-|P_{miss}|$

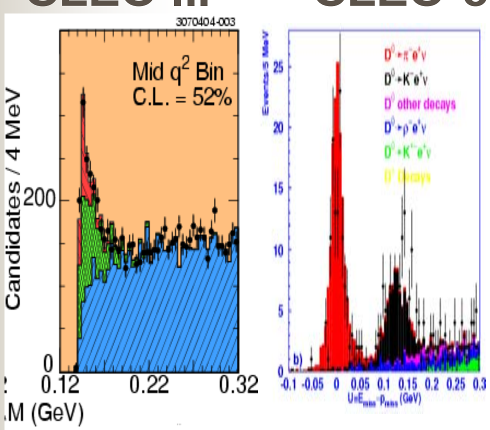
Signal component from fit to variable U

$$B(D^+ \to \overline{K}^0 e^+ \nu) = \frac{N(\overline{K}^0 e^+ \nu)}{\varepsilon(\overline{K}^0 e^+ \nu)\, N(D^-)}$$

From Monte Carlo/Data

From fit of M_{bc} and ΔE for number of tags

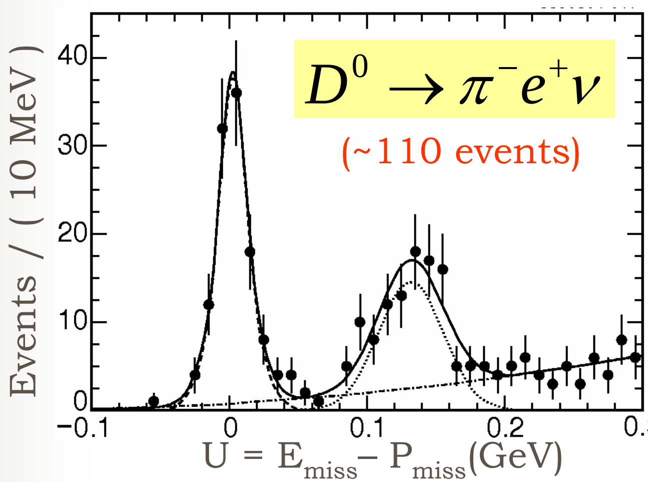
CLEO III **CLEO-c**

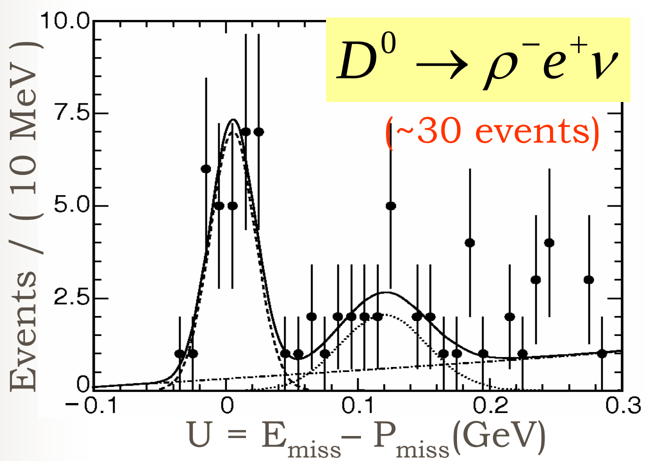


D→π l ν

Exclusive Semileptonic Decays

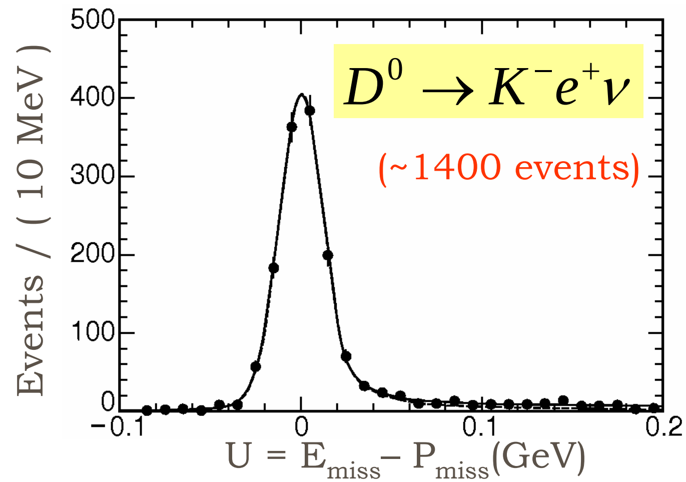
Cabibbo suppressed modes

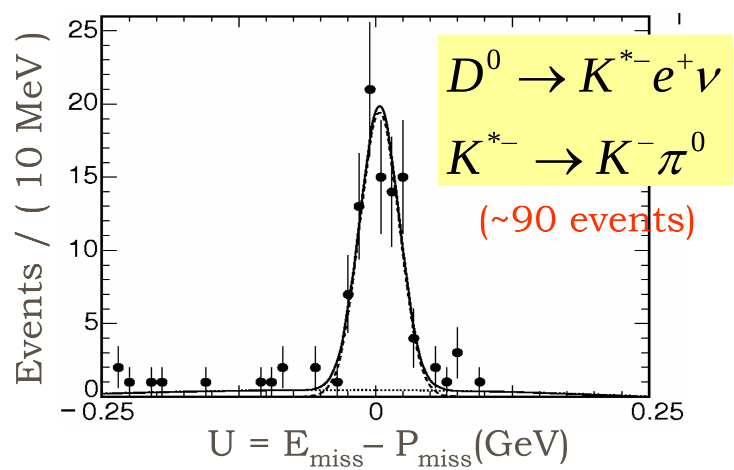




First Observation

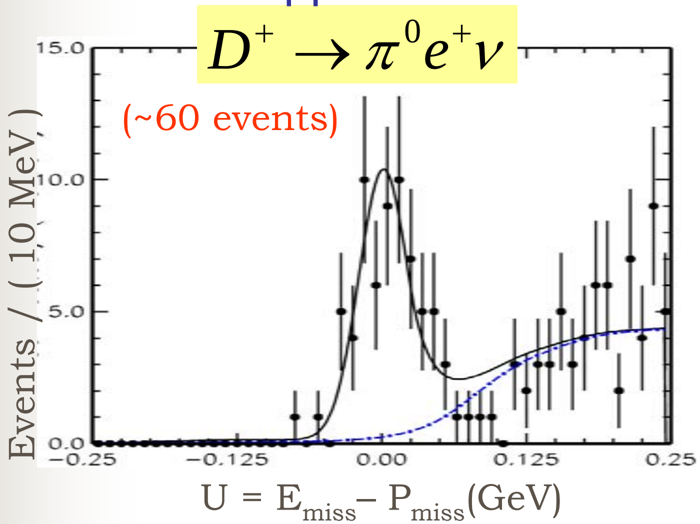
Cabibbo favored modes

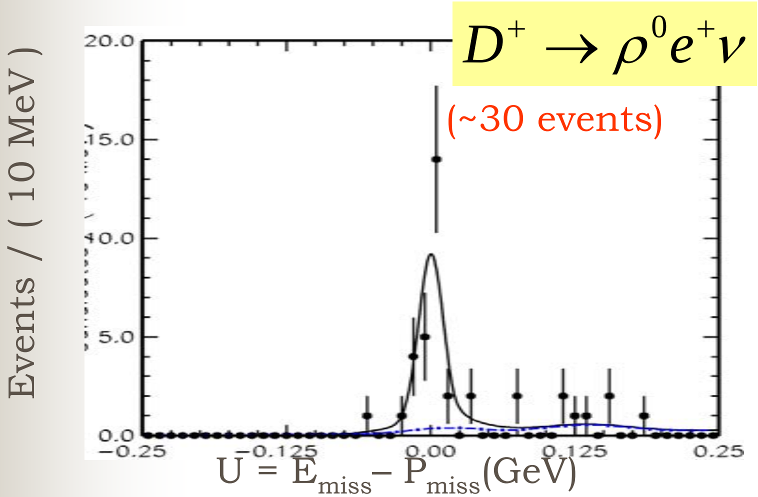




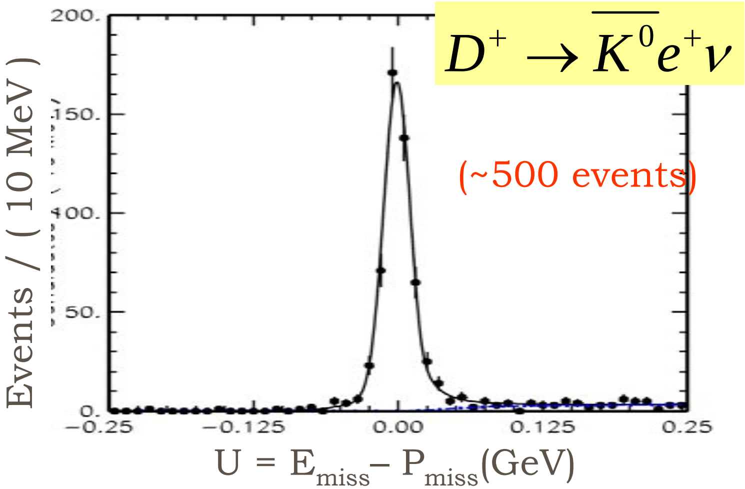
Exclusive Semileptonic Decays

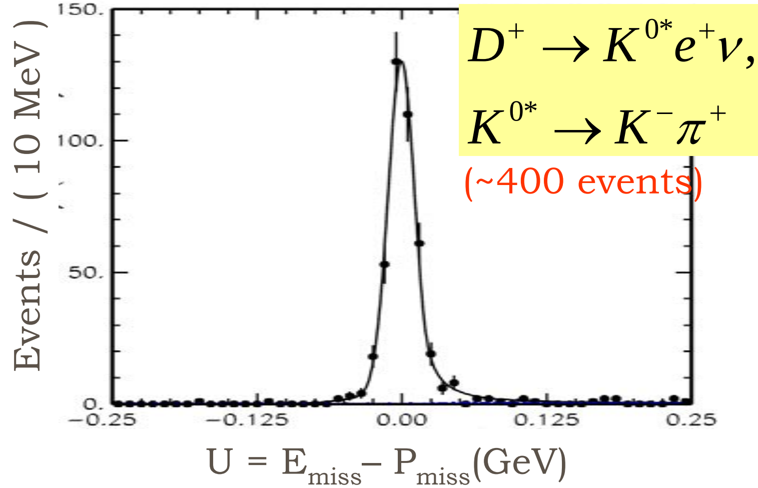
Cabibbo suppressed modes:





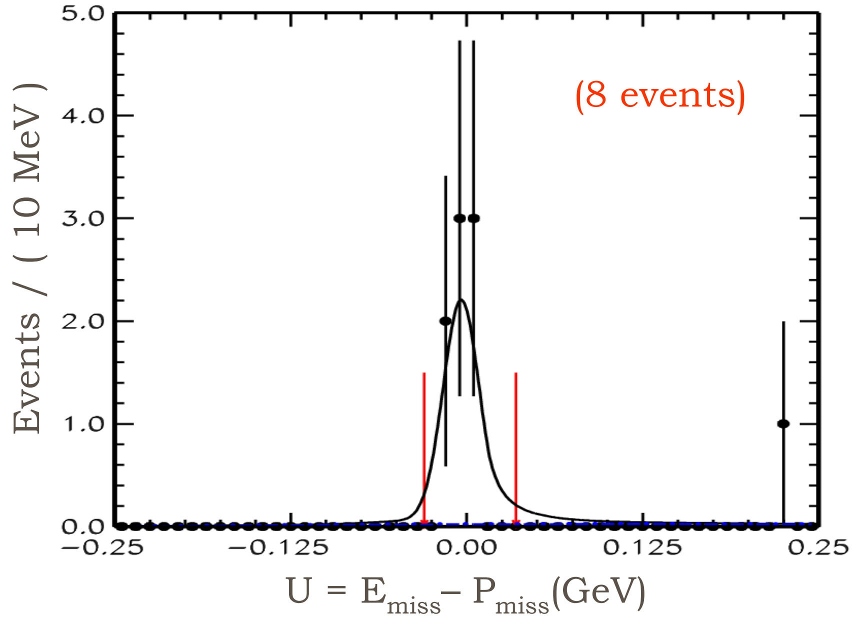
Cabibbo favored modes:





Exclusive Semileptonic Decays

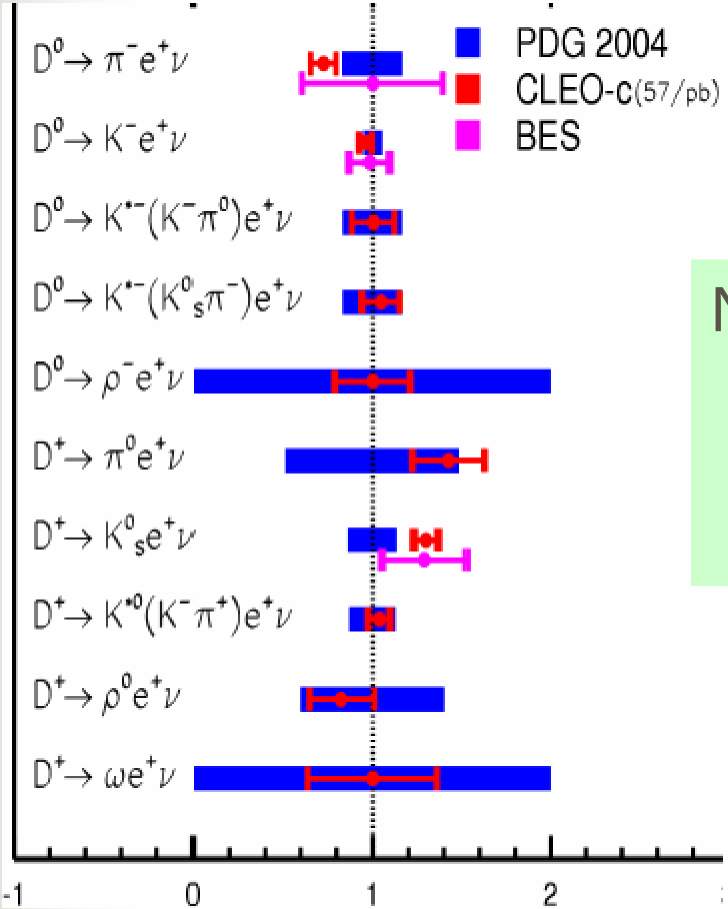
$D^+ \to \omega e^+ \nu$



First Observation

Exclusive Semileptonic Decays

Results from 57/pb



PRL 95 181802 (2005) D^o

PRL 95 181801 (2005) D^+

Next:

Form Factors from 281/pb

$K e \nu$ and $\pi e \nu$

q^2 resolution < 0.025 GeV^2

BES Updates:

Inclusive Semileptonic Decays

Motivation:

→BR(D→Xlν)

→Precision measurement of lepton momentum spectrum.

→Compare $\Gamma_{sl}(D^0)/\Gamma_{sl}(D^+)$

→Test HQT with $\Gamma_{sl}(D^0)/\Gamma_{sl}(D_s)$

Technique:

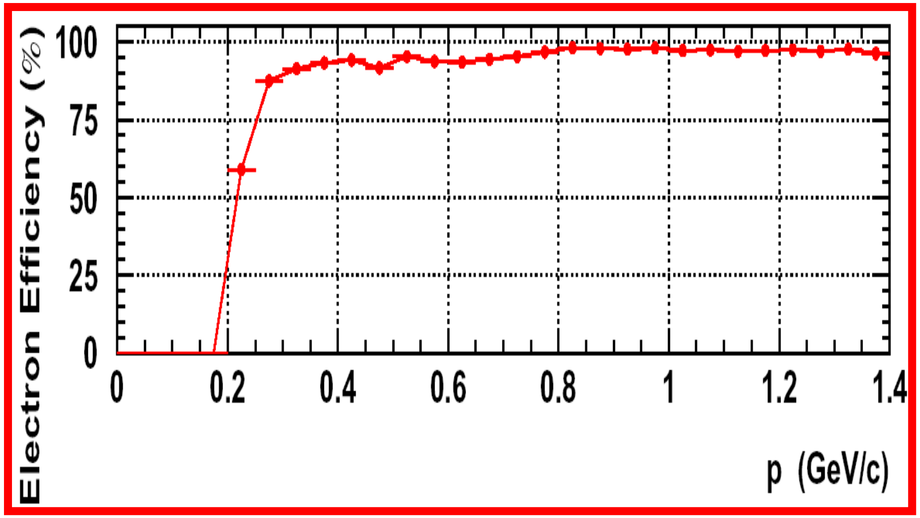
→D-Tag

→Electron ID

→Gold DTags only

- $K^-\pi^+$ and $K^-\pi^+\pi^+$

→Charge correlation



Inclusive Semileptonic Decays

From 281/pb - Preliminary

$\mathcal{B}(D^+ \rightarrow Xe^+\nu) = (16.13 \pm 0.20 \pm 0.34)\%$
(Σ D^+ exclusive =15.1 %)

$\mathcal{B}(D^0 \rightarrow Xe^+\nu) = (6.46 \pm 0.17 \pm 0.12)\%$
(Σ D^0 exclusive =6.1%)

$\Gamma_{sl}(D^+)/\Gamma_{sl}(D^0) = 0.985 \pm 0.028 \pm 0.015$

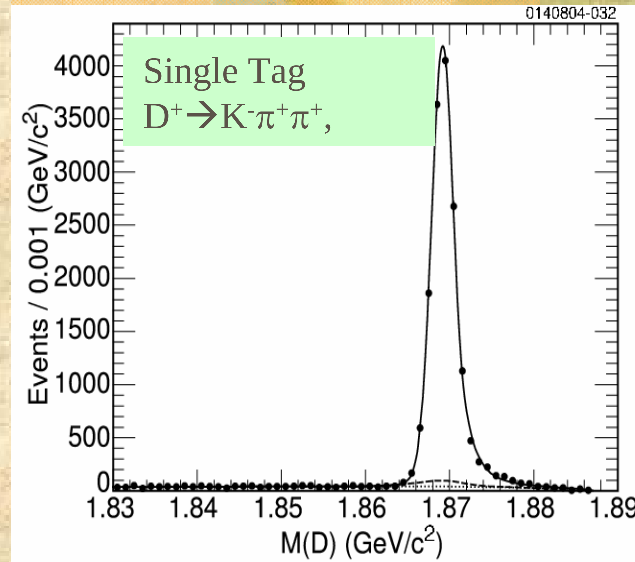
Soon: Electron momentum shape comparison

Hadronic D Branching Fractions

<u>Motivation:</u>

→Provide most precise measurement of D hadronic BRs.
→Many current measurements determined with respect to normalizing modes (*e.g.* $D \rightarrow K\pi$, $D \rightarrow K\pi\pi$).
→CLEO-c will provide absolute measurements.
→Counting D mesons provides DD production cross sections.

Double Tags



Single tags: $N_i = 2\, N_{DD} B_i \varepsilon_i$

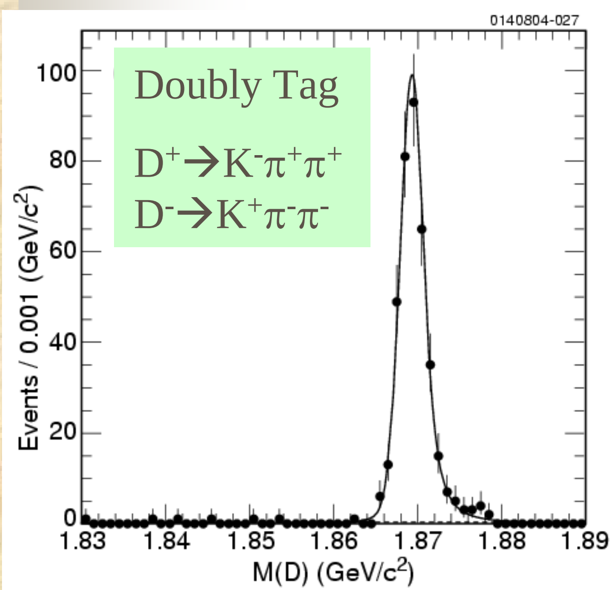
Double tags: $N_{ij} = N_{DD} B_i B_j \varepsilon_{ij}$

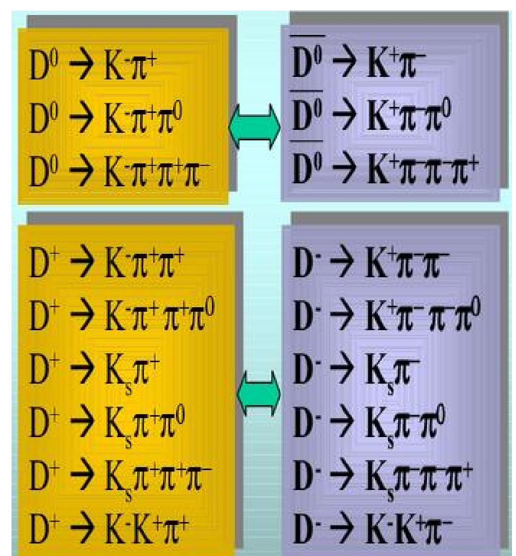
$$B_i = \frac{N_{ij}\varepsilon_j}{N_j \varepsilon_{ij}}$$

$$N_{DD} = \frac{N_i N_j \varepsilon_{ij}}{2\, N_{ij} \varepsilon_i \varepsilon_j}$$

Syst unc cancels.

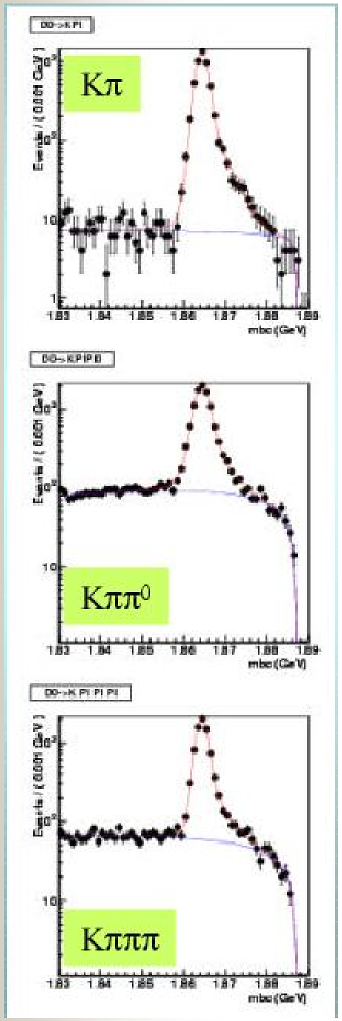
- To first order Bi independent of tag modes and efficiencies.
- Simultaneous fit for all BR and cross sections.
- All correlations taken into account.





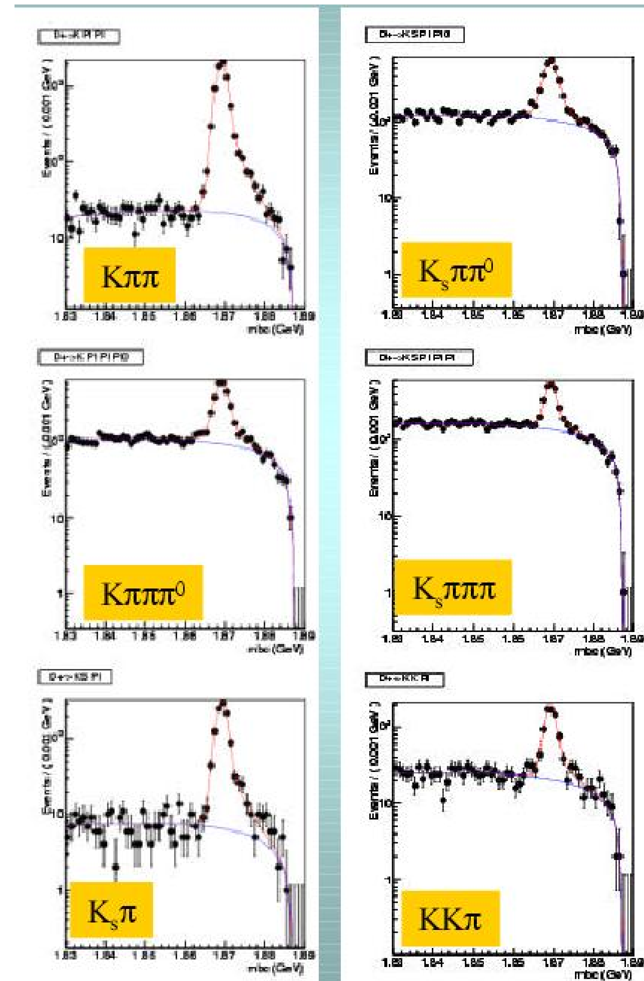
Fits

D0



Mode	N_D ($x10^3$)	$N_{\bar{D}}$ ($x10^3$)	ε_D (%)
$K\pi$	5.11±0.07	5.15±0.07	65.7±0.3
$K\pi\pi^0$	9.51±0.11	9.47±0.11	33.2±0.1
$K\pi\pi\pi$	7.44±0.09	7.43±0.09	44.6±0.2
$K\pi\pi$	7.56±0.09	7.56±0.09	51.7±0.2
$K\pi\pi\pi^0$	2.45±0.07	2.39±0.07	27.2±0.2
$K_s\pi$	1.10±0.04	1.13±0.04	45.6±0.4
$K_s\pi\pi^0$	2.59±0.07	2.50±0.07	23.4±0.2
$K_s\pi\pi\pi$	1.63±0.06	1.58±0.06	31.4±0.2
$KK\pi$	0.64±0.03	0.61±0.03	42.6±0.5

D+



Line shapes include ISR, resolution, beam energy spread.
Efficiencies include FSR correction.

Results

D^0 Modes

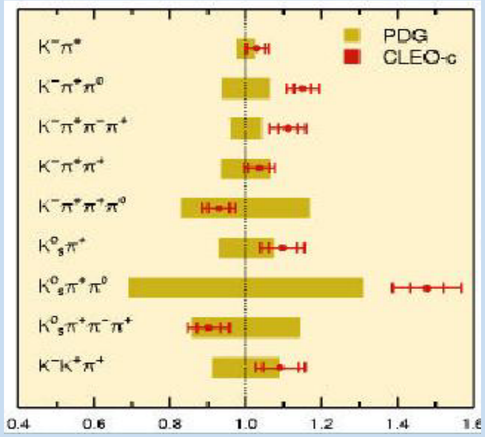
Parameter	Fitted Value (%)
N($D^0\overline{D^0}$)	$(2.006 \pm 0.038 \pm 016) \times 10^5$
$\mathcal{B}(D^0 \to K^-\pi^+)$	$(3.91 \pm 0.08 \pm 0.09)$ %
$\mathcal{B}(D^0 \to K^-\pi^+\pi^0)$	$(14.94 \pm 0.30 \pm 0.47)$ %
$\mathcal{B}(D^0 \to K^-\pi^+\pi^+\pi^-)$	$(8.29 \pm 0.17 \pm 0.32)$ %

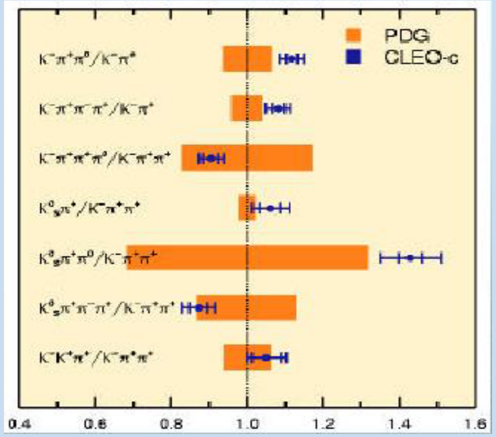
D^+ Modes

Parameter	Fitted Value (%)
N(D^+D^-)	$(1.558 \pm 0.038 \pm 012) \times 10^5$
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+)$	$(9.52 \pm 0.25 \pm 0.27)$ %
$\mathcal{B}(D^+ \to K^-\pi^+\pi^+\pi^0)$	$(6.04 \pm 0.18 \pm 0.22)$ %
$\mathcal{B}(D^+ \to K_s\pi^+)$	$(1.55 \pm 0.05 \pm 0.06)$ %
$\mathcal{B}(D^+ \to K_s\pi^+\pi^0)$	$(7.17 \pm 0.21 \pm 0.38)$ %
$\mathcal{B}(D^+ \to K_s\pi^+\pi^+\pi^-)$	$(3.20 \pm 0.11 \pm 0.16)$ %
$\mathcal{B}(D^+ \to K^+K^-\pi^+)$	$(0.97 \pm 0.04 \pm 0.04)$ %

- Agreement with PDG.
- PDG numbers are correlated among modes.
- CLEO-c numbers correlated.
- CLEO-c include FSR correction.

PRL 95 121801 (2005)





Summary

CLEOIII

First experimental limit on localized weak in semileptonic B decays.

CLEO-c

Update on $D^+ \to \mu^+\nu$

Limit on $D^+ \to \tau^+\nu$ (preliminary)

Exclusive semileptonic D branchings (FF soon)

- two "first observations"

Inclusive semileptonic D branchings (spectrum soon)

- Ratio for charged to neutral semileptonic widths ~1

Absolute hadronic branchings shown.