First CLEO-c Results on Exclusive D^0 Semileptonic Decays

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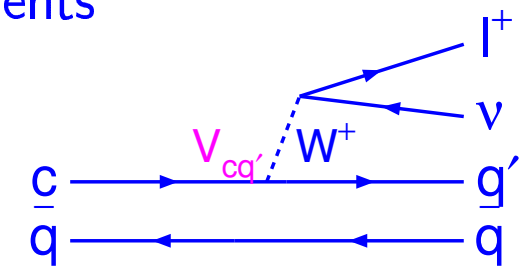
- Motivation
- Analysis Technique
- Overview of Event Selection
- Results (Preliminary)
- Summary

D^0 Semileptonic Decays and V_{cs} and V_{cd}

- D Semileptonic Decays and CKM matrix elements

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



- uncertainty is 13% for V_{cs} and 7% for V_{cd}
- Gold-plated Modes: $D^0 \to K^- e^+ \nu$ and $D^0 \to \pi^- e^+ \nu$

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cq}|^2 p_P^3 \left| f_+(q^2) \right|^2$$

  - also $D^0 \to K^{*-} e^+ \nu$ and $D^0 \to \rho^- e^+ \nu$
- Measure V_{cs} and V_{cd}
- Test Lattice QCD/other theories (form factors).
- Improve V_{ub} measurement

Analysis Technique

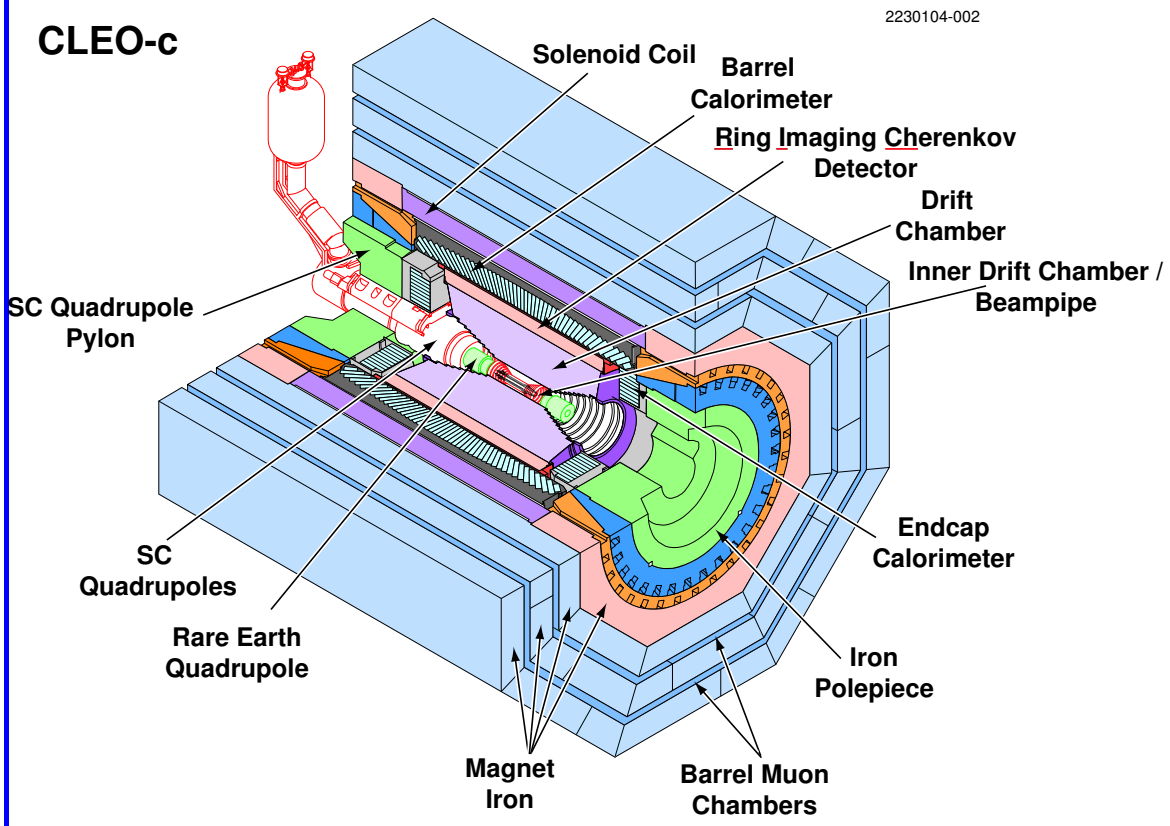
- How to measure absolute $\mathcal{B}$?
  - D Tagging:

$$\mathcal{B} = \frac{N_{signal}/\epsilon_{signal}}{N_{tag}/\epsilon_{tag}} = \frac{N_{signal}}{N_{tag}\epsilon_{signal}/\epsilon_{tag}} \quad (1)$$

N_{tag}: number of events with a fully reconstructed tagging D
N_{signal}: number of events with exclusive D semileptonic decays AND a fully reconstructed tagging D
$\epsilon_{h\ell\nu} = \epsilon_{signal}/\epsilon_{tag}$ for $h\ell\nu$

- Advantage:
  - large cross section, low multiplicity, no fragmentation
  - "background free" for threshold production at the $\psi(3770)$;
  - many systematics cancel in $\mathcal{B}$

CESR-c and CLEO-c

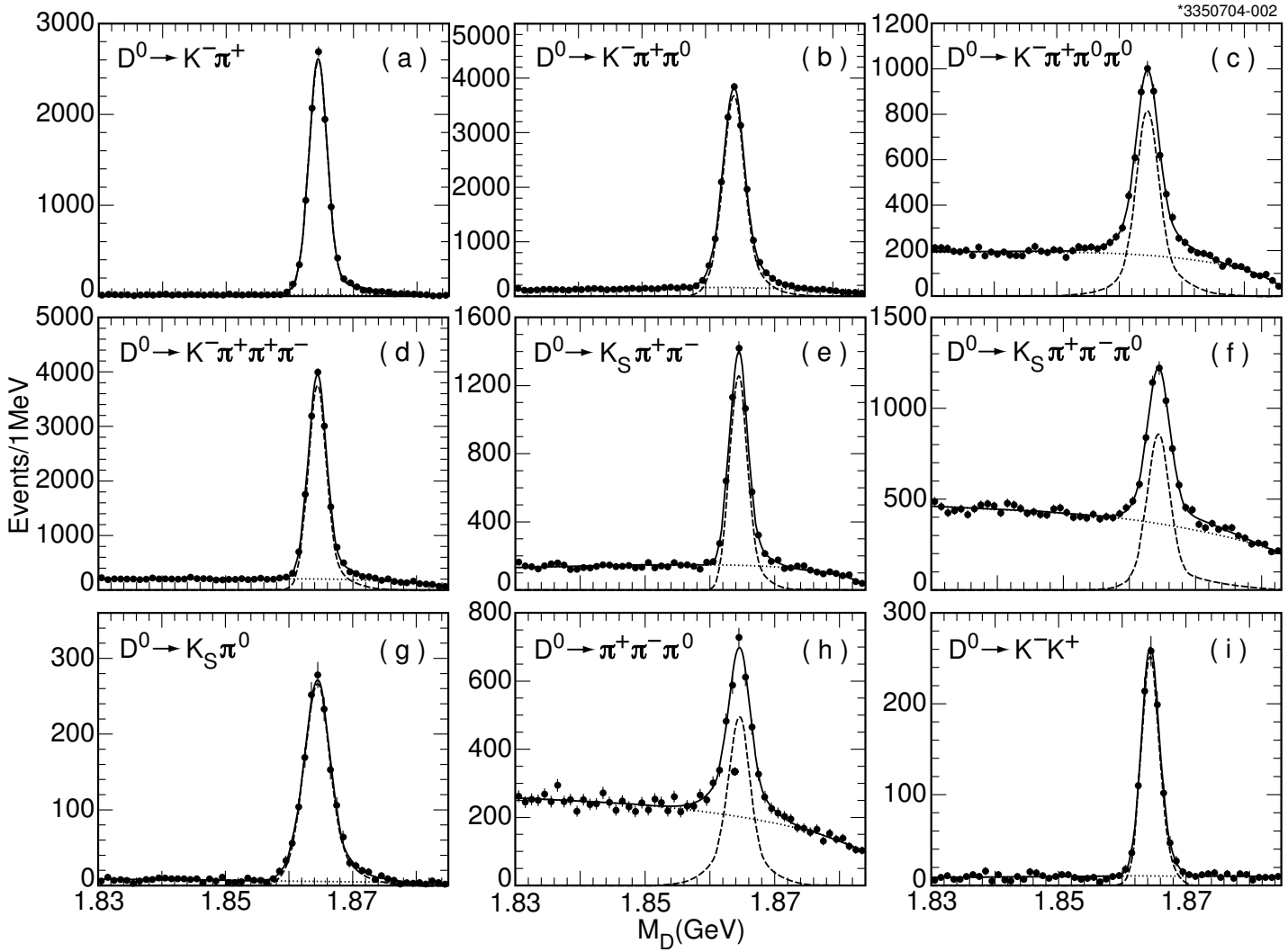


- CESR (10 GeV) $\rightarrow$ CESR-c (3-4GeV) w/ 12 wigglers for damping at low energies
- 6 last summer, all done
- 10/03-4/04 6 wiggler initial run $\mathcal{L} \sim 5 \times 10^{31} cm^{-2} s^{-1}$ as expected
- goal $\mathcal{L} \sim 3 \times 10^{32} cm^{-2} s^{-1}$
- CLEO $\rightarrow$ CLEO-c
  B: 1.5T $\rightarrow$ 1.0T;
  Vertex: Silicon$\rightarrow$6 layer DR
- Initial Run:
  60 pb^{-1} at the $\psi(3770)$,
  3 pb^{-1} at the $\psi(2S)$,
  20 pb^{-1} at 3.67 GeV.
- μ chambers $p > 1.0$ GeV/c

Overview of Event Selection

- D Tagging:
  - $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^0\pi^0$, $K^-\pi^+\pi^+\pi^-$, $K_S\pi^0$, $K_S\pi^+\pi^-$, $K_S\pi^+\pi^-\pi^0$, $\pi^+\pi^-\pi^0$ and K^-K^+.
  - $M_{bc} = \sqrt{E^2_{beam} - p^2_D}$ and $\Delta E = E_D - E_{beam}$
- D Semileptonic Decays: $U = E_{miss} - p_{miss}$ peaks at zero.
- π^0: $\sim 3\sigma$ mass cut, constrained to its mass;
- K^0_S: $\sim 3\sigma$ mass cut, constrained to a vertex fit;
- Electron: E/p, dE/dx and RICH if available
- Bremsstrahlung recovery for electron;
- Hadron ID: 3σ dE/dx for low momentum track; RICH+dE/dx combined for high momentum track if RICH available, otherwise 3σ dE/dx;
- $K^{*-}(K^-\pi^0)$ within 100 MeV and $\rho^-(\pi^-\pi^0)$ within 150 MeV of their masses.

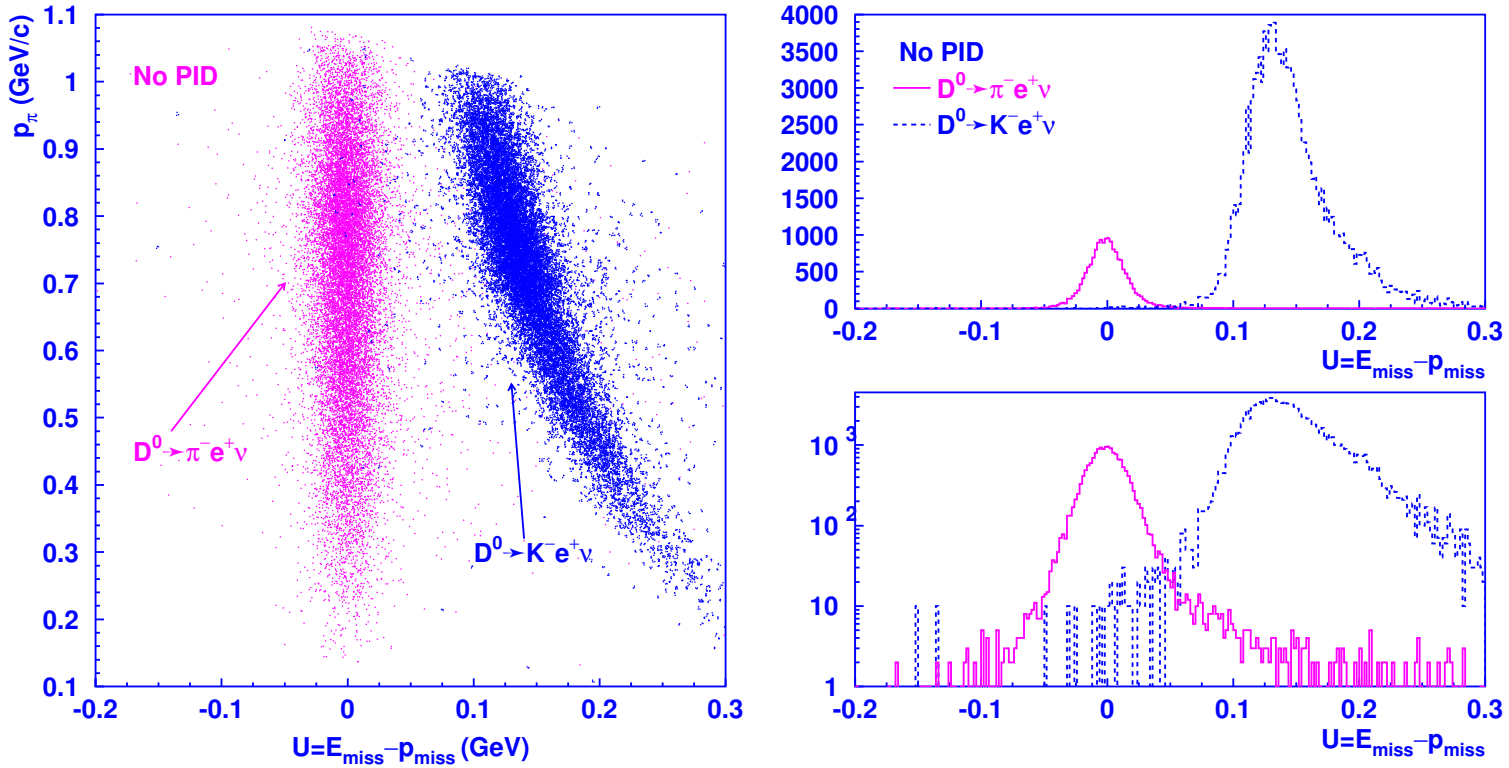
Single Tagging D's: Data



- 60K tagging D^0

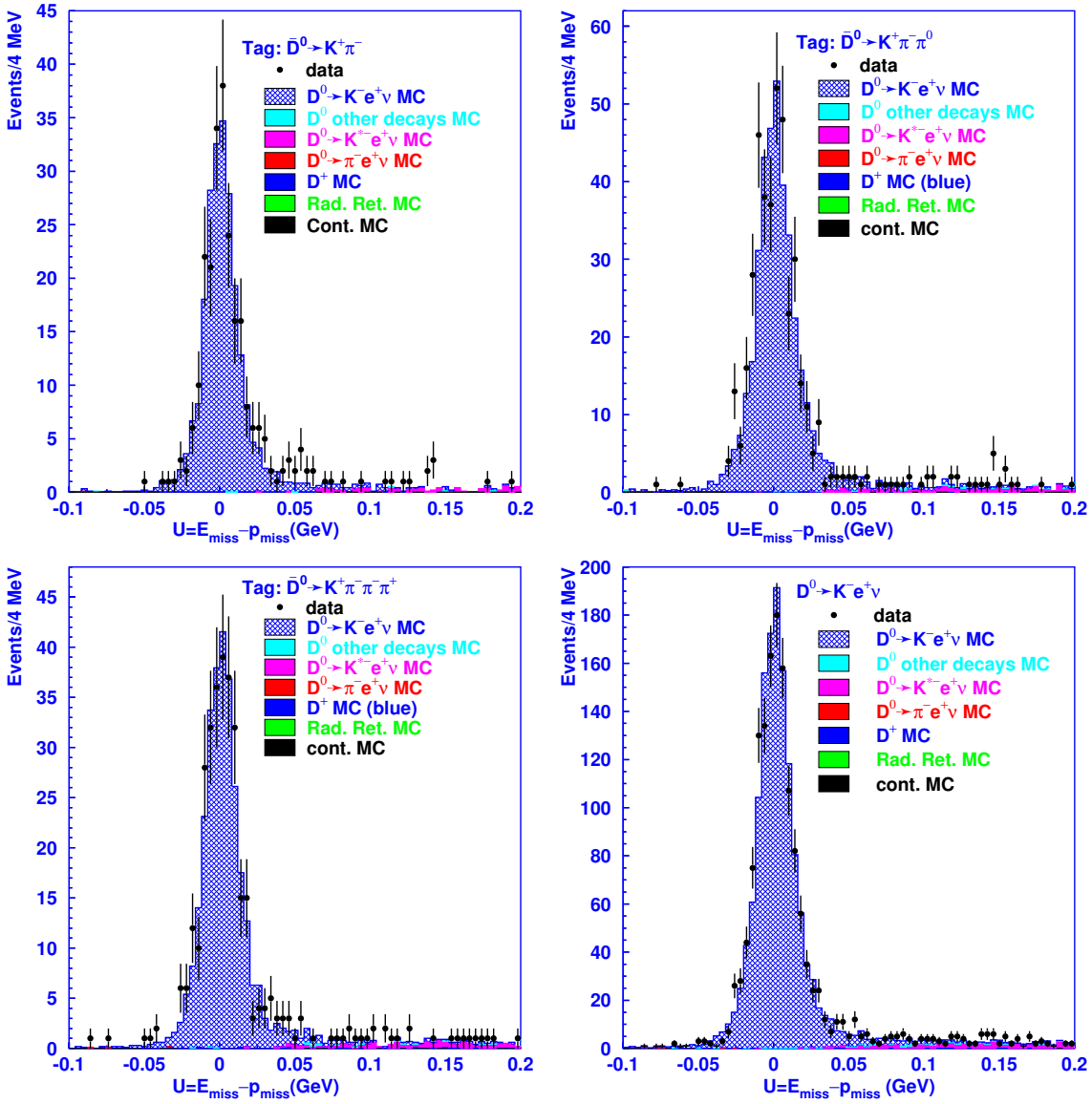
Hadron ID for $D^0 \to \pi^- e^+ \nu$

- Background: $D^0 \to K^- e^+ \nu \Rightarrow D^0 \to \pi^- e^+ \nu$ (no hadron ID)
  $(\frac{\mathcal{B}(D^0 \to \pi^- e^+ \nu)}{\mathcal{B}(D^0 \to K^- e^+ \nu)} = 0.1)$



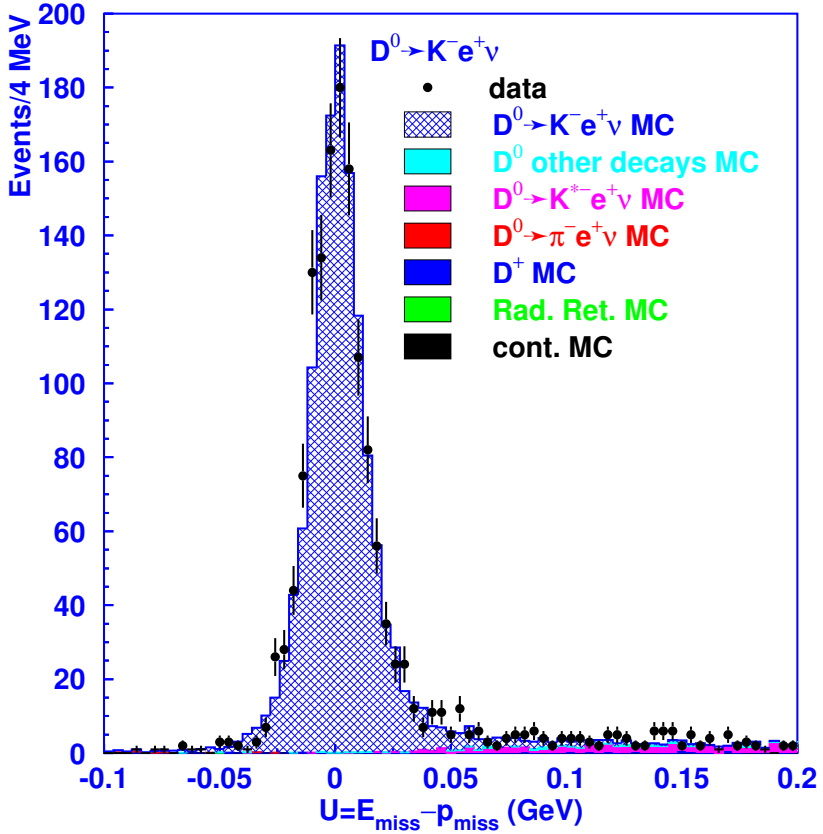
- well separated, tight hadron ID not necessary.

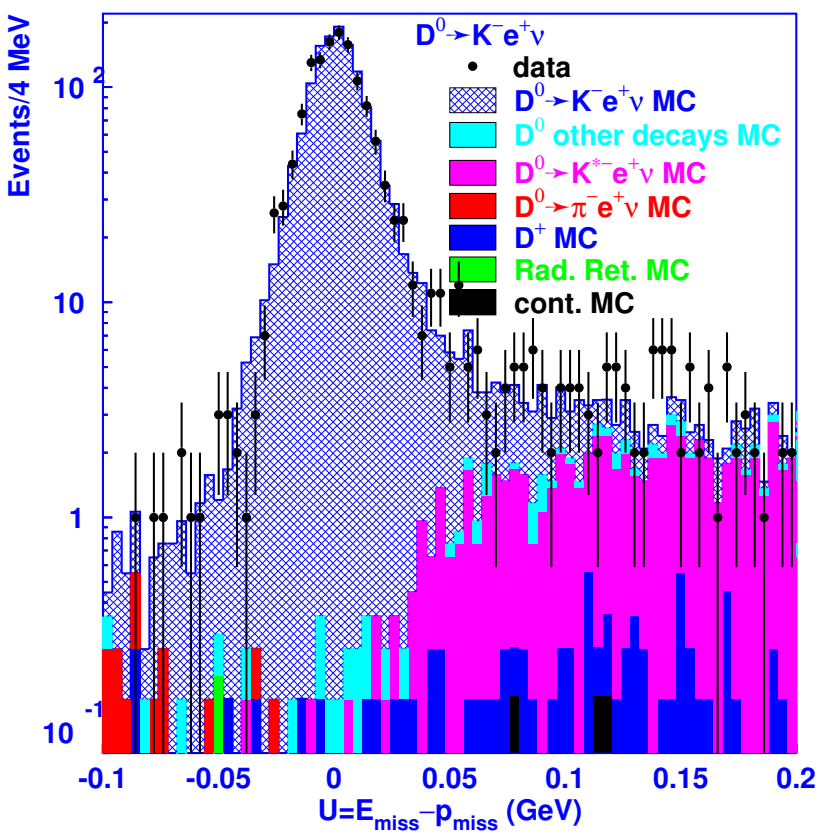
$D^0 \to K^- e^+ \nu$: data vs. MC



Backgrounds for $D^0 \to K^- e^+ \nu$

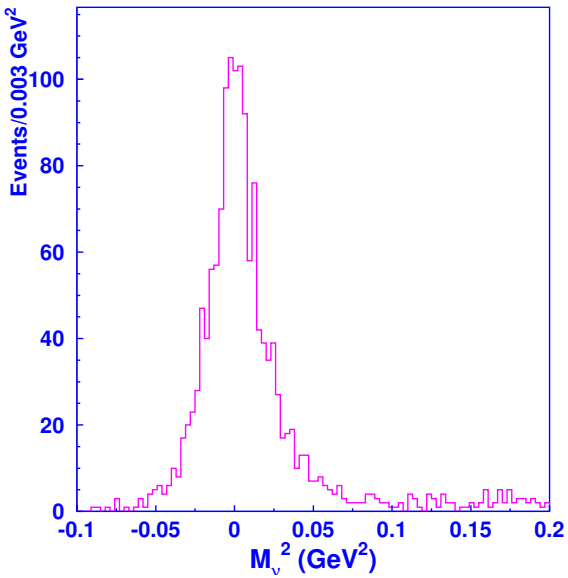
- Backgrounds for $D^0 \to K^- e^+ \nu$: $D^0 \to K^{*-} e^+ \nu$

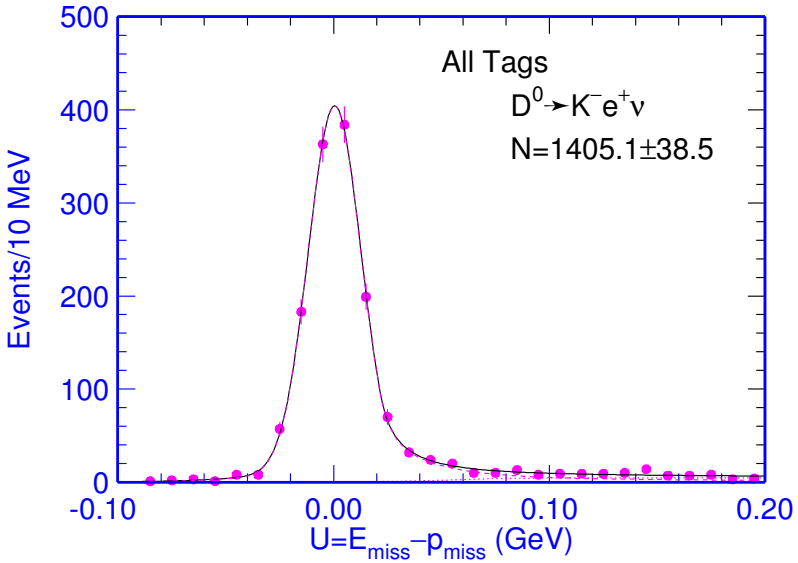


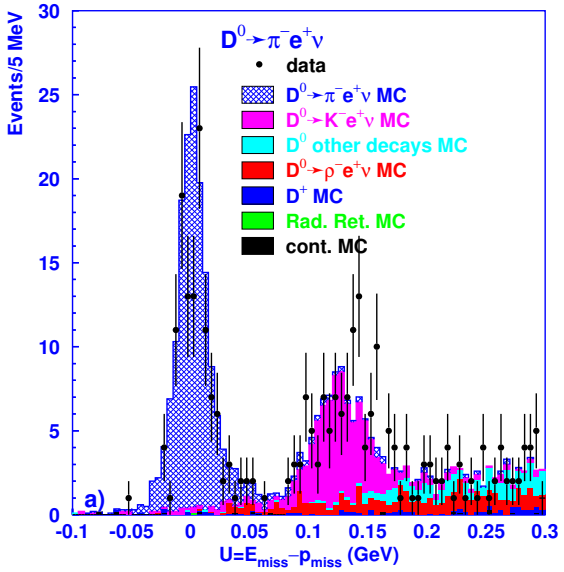


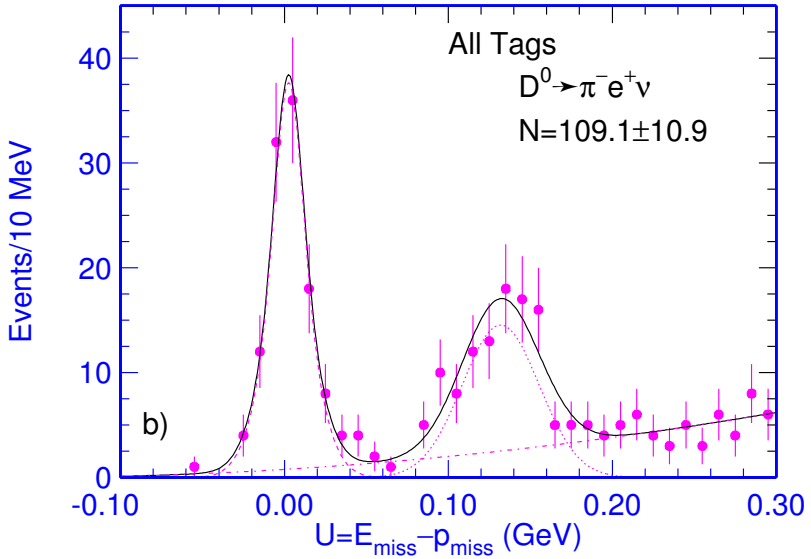
- "background free"

Results of $D^0 \to K^- e^+ \nu$ and $D^0 \to \pi^- e^+ \nu$

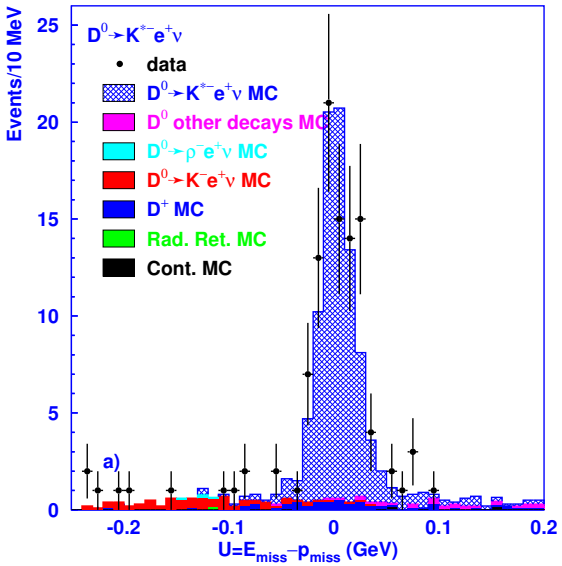


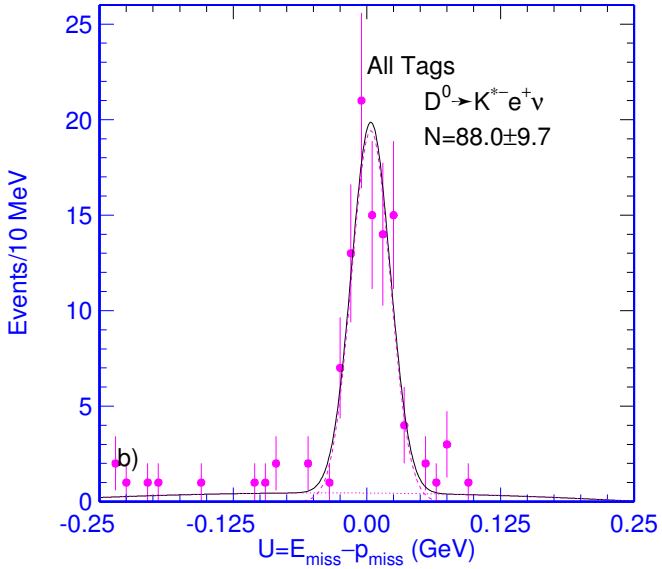


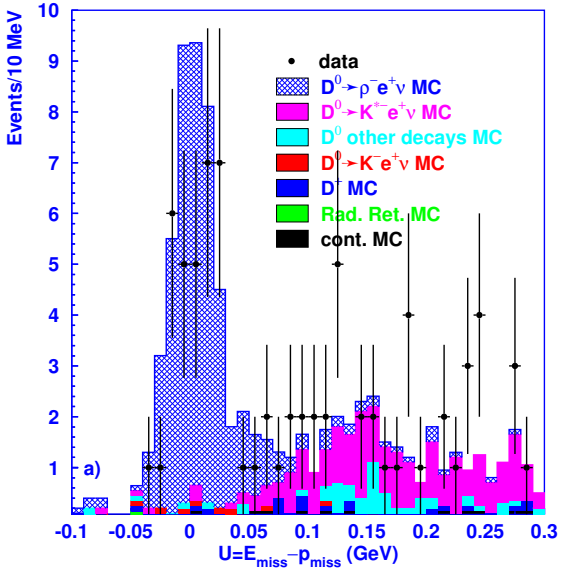


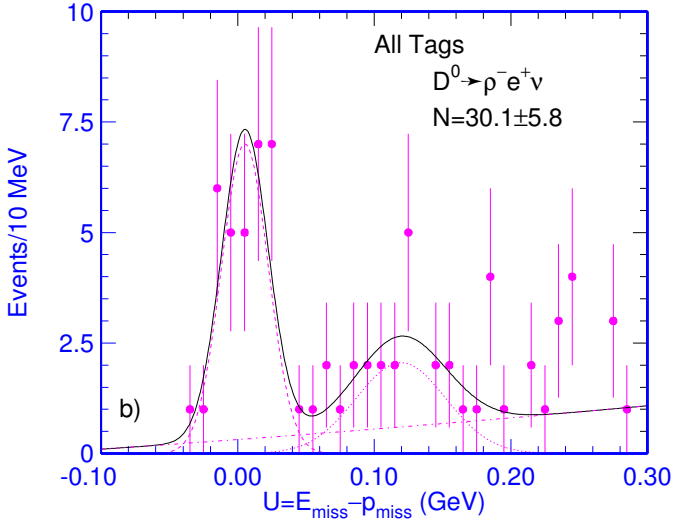


Results for $D^0 \to K^{*-} e^+ \nu$ and $D^0 \to \rho^- e^+ \nu$









Results and V_{cs}, V_{cd}

- $\mathcal{B}$ (Preliminary)

Decays	$\mathcal{B}$	PDG
$D^0 \to K^- e^+ \nu$	$(3.52 \pm 0.10 \pm 0.25)\%$	$(3.58 \pm 0.18)\%$
$D^0 \to \pi^- e^+ \nu$	$(0.25 \pm 0.03 \pm 0.02)\%$	$(0.36 \pm 0.06)\%$
$D^0 \to K^{*-} e^+ \nu$	$(2.07 \pm 0.23 \pm 0.18)\%$	$(2.15 \pm 0.35)\%$
$D^0 \to \rho^- e^+ \nu$	$(0.19 \pm 0.04 \pm 0.02)\%$	none

Systematic error is dominated by 3%/track and 4.4%/π^0 and these errors will improve with more data and further study

- V_{cs} and V_{cd}

Model	V_{cs}	V_{cd}
Quenched	$1.070^{+0.019}_{-0.020} \pm 0.065 \pm 0.040$	$0.226^{+0.010}_{-0.011} \pm 0.024 \pm 0.014$
Unquenched	$0.953^{+0.008}_{-0.008} \pm 0.051 \pm 0.036$	$0.204^{+0.003}_{-0.003} \pm 0.010 \pm 0.013$
LCSR	$0.970^{+0.009}_{-0.019} \pm 0.137 \pm 0.037$	$0.217^{+0.003}_{-0.006} \pm 0.037 \pm 0.014$
Simple pole*	$1.000 \pm 0.053 \pm 0.038$	$0.221 \pm 0.010 \pm 0.014$

* $f_+^\pi(0) = 0.64 \pm 0.03(stat.)$ and $f_+^K(0) = 0.75 \pm 0.04(stat.)$ from the unquenched LQCD used.

- More precise LQCD results needed

Summary

- Improved $\mathcal{B}$'s (preliminary).

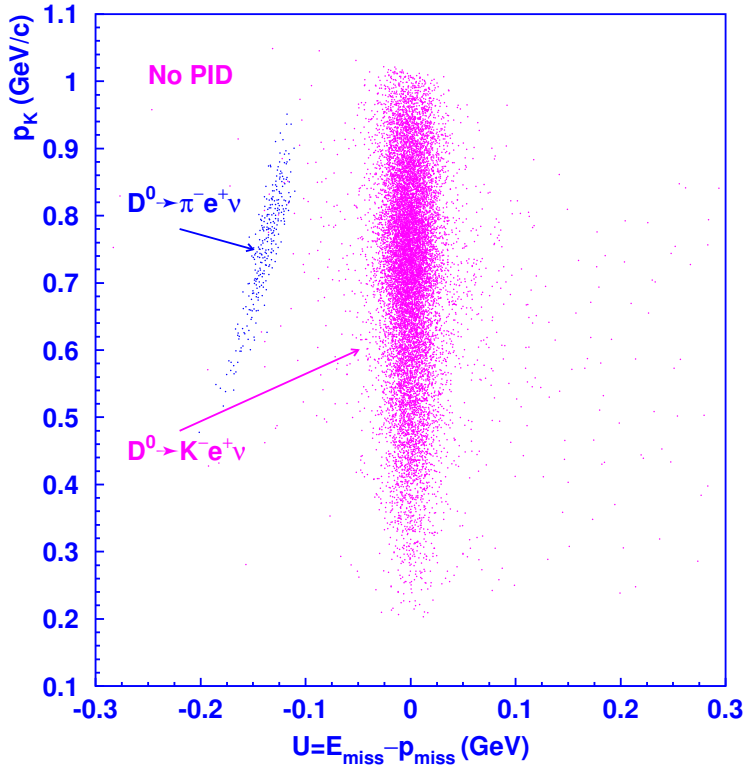
Decays	$\mathcal{B}$	PDG
$D^0 \to K^- e^+ \nu$	$(3.52 \pm 0.10 \pm 0.25)\%$	$(3.58 \pm 0.18)\%$
$D^0 \to \pi^- e^+ \nu$	$(0.25 \pm 0.03 \pm 0.02)\%$	$(0.36 \pm 0.06)\%$
$D^0 \to K^{*-} e^+ \nu$	$(2.07 \pm 0.23 \pm 0.18)\%$	$(2.15 \pm 0.35)\%$
$D^0 \to \rho^- e^+ \nu$	$(0.19 \pm 0.04 \pm 0.02)\%$	none
$\frac{\mathcal{B}(D^0 \to \pi^- e^+ \nu)}{\mathcal{B}(D^0 \to K^- e^+ \nu)}$	$(7.0 \pm 0.7 \pm 0.3)\%$	$(10.1 \pm 1.8)\%$
$\frac{\mathcal{B}(D^0 \to \rho^- e^+ \nu)}{\mathcal{B}(D^0 \to K^{*-} e^+ \nu)}$	$(9.2 \pm 2.0 \pm 0.8)\%$	none

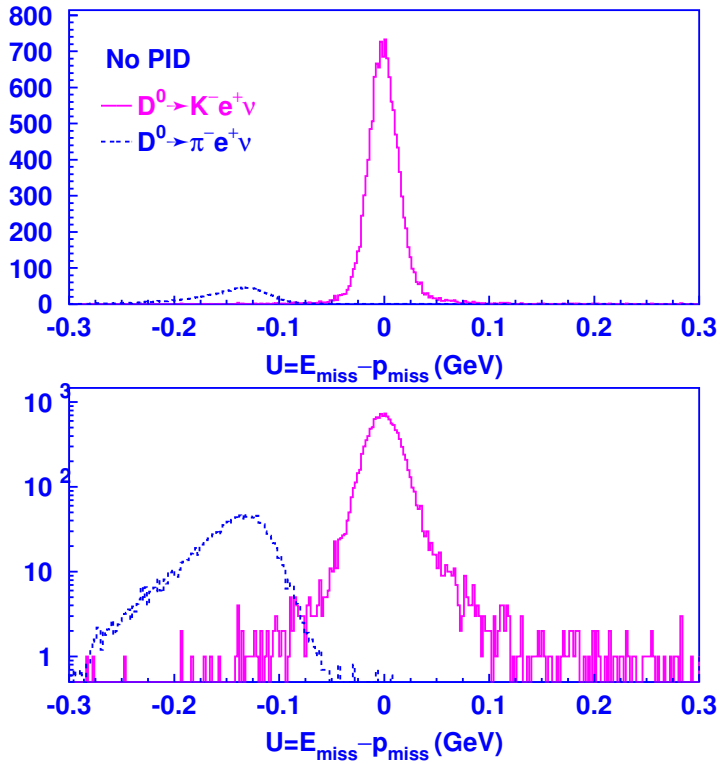
  CLEO III: $\frac{\mathcal{B}(D^0 \to \pi^- \ell^+ \nu)}{\mathcal{B}(D^0 \to K^- \ell^+ \nu)} = (8.2 \pm 0.6 \pm 0.5)\%$

- First observation of $D^0 \to \rho^- e^+ \nu$.
- V_{cs} and V_{cd}, precise theoretic inputs needed.
- CLEO Collaboration, hep-ex/0408077 (ICHEP'04), .
- Fall 2004, data taking resumes, 3 fb^{-1} at the $\psi(3770)$, 50X larger sample. 3 millon tagged D^0 and 1.5 million tagged D^+;
- more precision results will come out soon;

Hadron ID for $D^0 \to K^- e^+ \nu$

- Backgrounds: $D^0 \to \pi^- e^+ \nu \Rightarrow D^0 \to K^- e^+ \nu$ (no hadron ID) $(\frac{\mathcal{B}(D^0 \to \pi^- e^+ \nu)}{\mathcal{B}(D^0 \to K^- e^+ \nu)} = 0.1)$





- well separated (threshold prod.), tight hadron ID not necessary.
- Backgrounds: $D^0 \to K^{*-} e^+ \nu$ $(K^{*-} \to K^- \pi^0)$ with $\not\pi^0$.