Precision Measurements of $D^0 \to K^-\ell^+\nu$ and $D^0 \to \pi^-\ell^+\nu$ at CLEO III

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- Introduction
- Overview of Analysis Technique
- Results
- Summary

$D^0 \to K^-\ell^+\nu$ **and** $D^0 \to \pi^-\ell^+\nu$

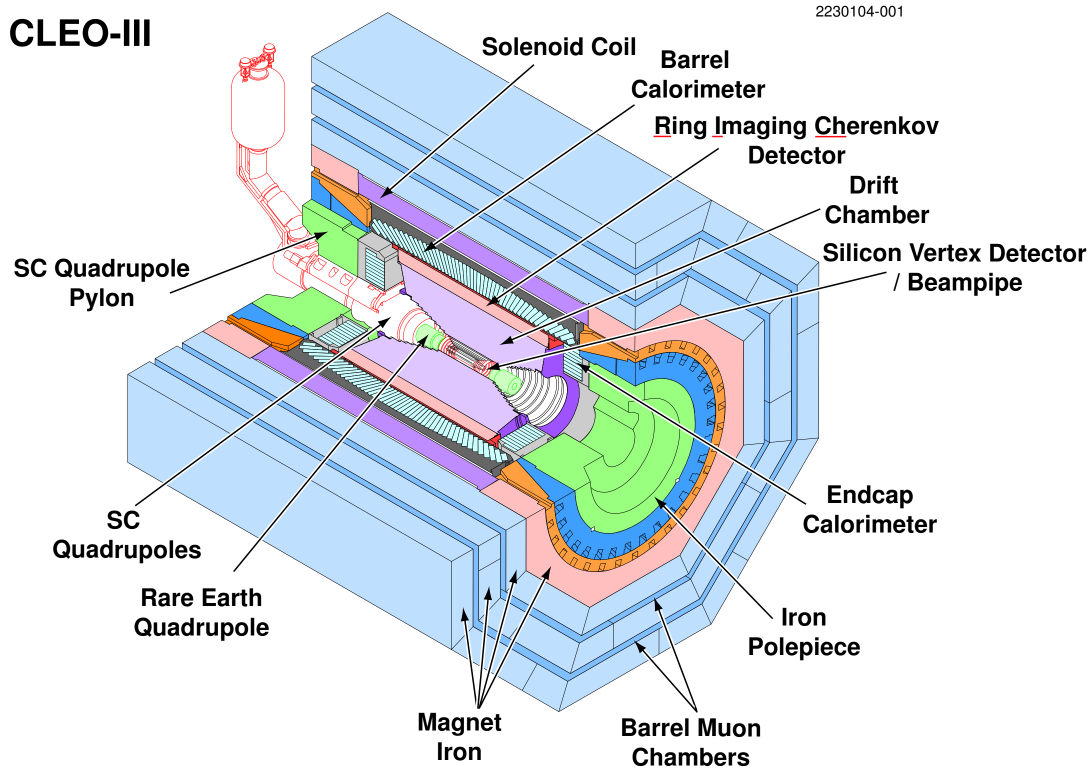
- $D^0 \to K^-\ell^+\nu$ and $D^0 \to \pi^-\ell^+\nu$

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

- With small data samples, we usually measure
  - ◇ $R_0 = \frac{\mathcal{B}(D^0 \to \pi^-\ell^+\nu)}{\mathcal{B}(D^0 \to K^-\ell^+\nu)}$
  - ◇ $\frac{d\Gamma}{\Gamma dq^2} = \frac{1}{\Gamma} \frac{G_F^2}{24\pi^3} \left|V_{cq}\right|^2 p_P^3 \left|f_+(q^2)\right|^2$
- Quantities we want to measure:
  - ◇ $\frac{V_{cd}}{V_{cs}}$ or $\frac{f_+^\pi(0)}{f_+^K(0)}$;
  - ◇ form factors ($B \to \pi\ell\nu$: V_{ub} measurement)

CLEO III Detector

- The CLEO III detector:



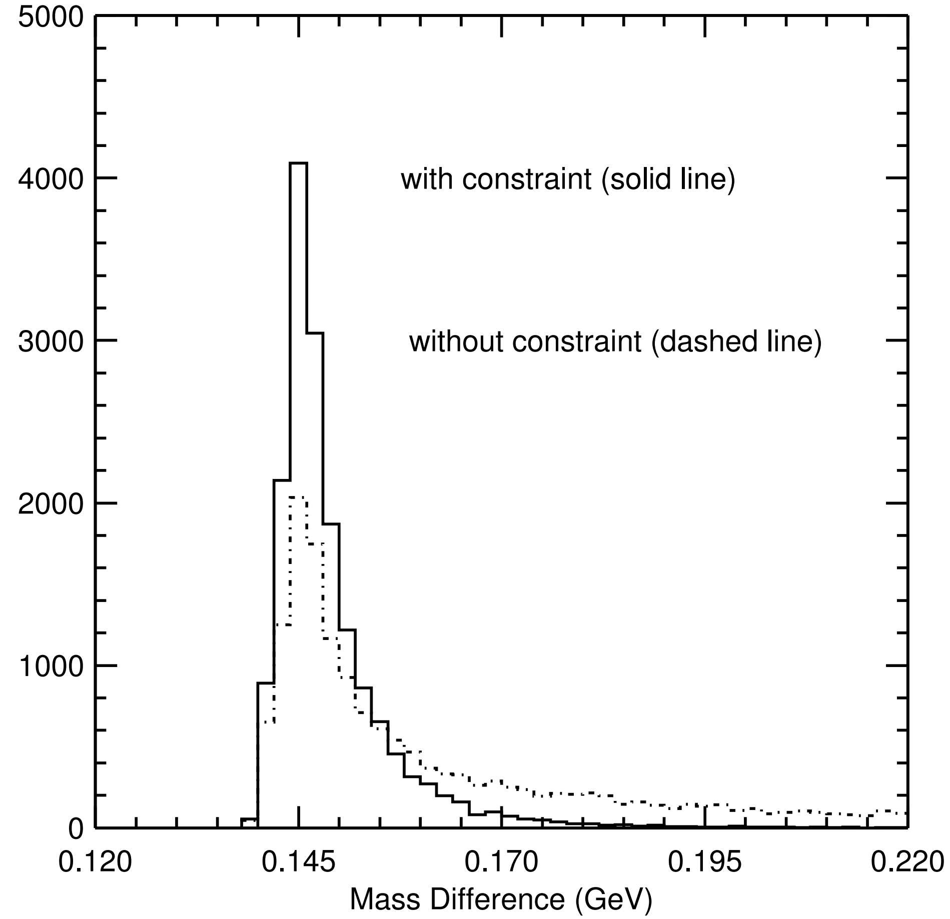
- Important update: RICH provides good π/K separation

Analysis Technique

- To fully reconstruct $D^0 \to K^-/\pi^-\ell^+\nu$:
  - ◇ $D^{*+} \to D^0\pi_s^+$ to tag $D^0 \to K^-/\pi^-\ell^+\nu$
  - ◇ using neutrino reconstruction:

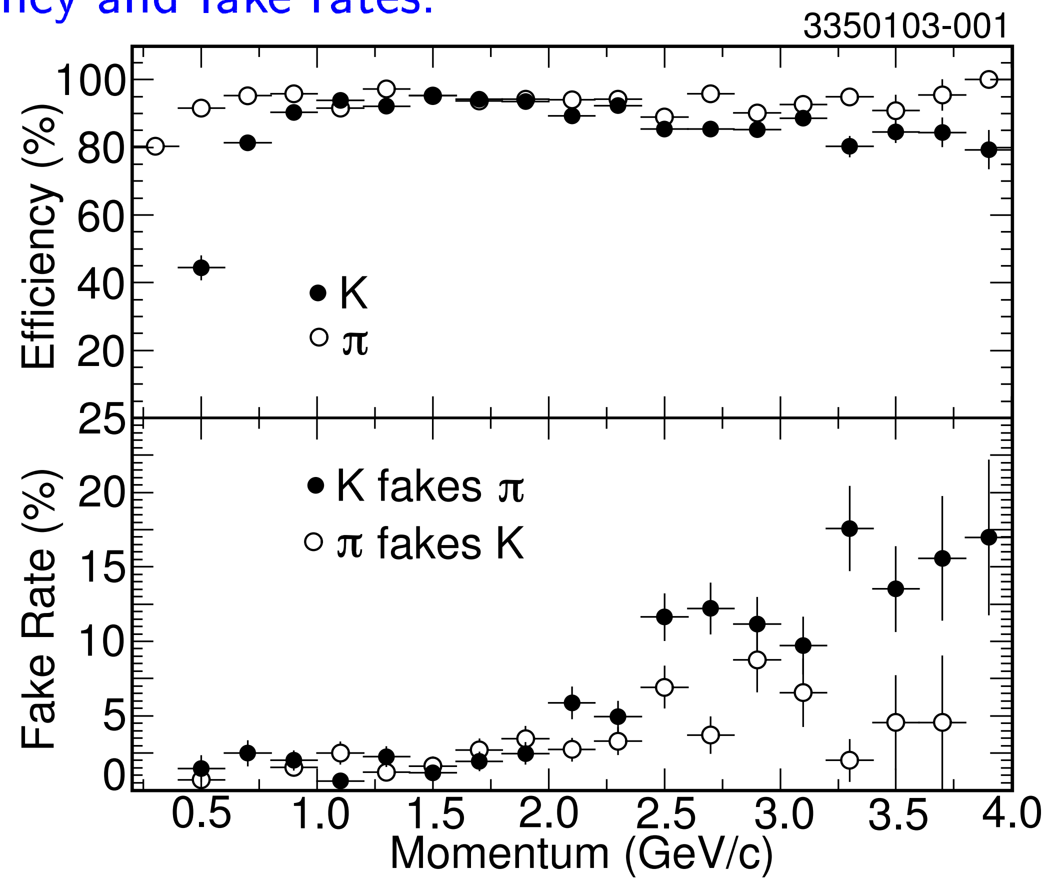
$$\vec{p}_\nu = \vec{p}_{miss} = -\sum_{event} \vec{p}_i$$

    - ▷ constrain $M_{h\ell\nu} = M_{D^0}$.
  - ◇ $\Delta M = M_{(h\ell\nu)\pi_s^+} - M_{h\ell\nu}$
- electron ID: E/p, dE/dx and RICH if available
- μ ID: μ chamber and Calorimeter info used.
- hadron ID: RICH+dE/dx



Hadron Identification

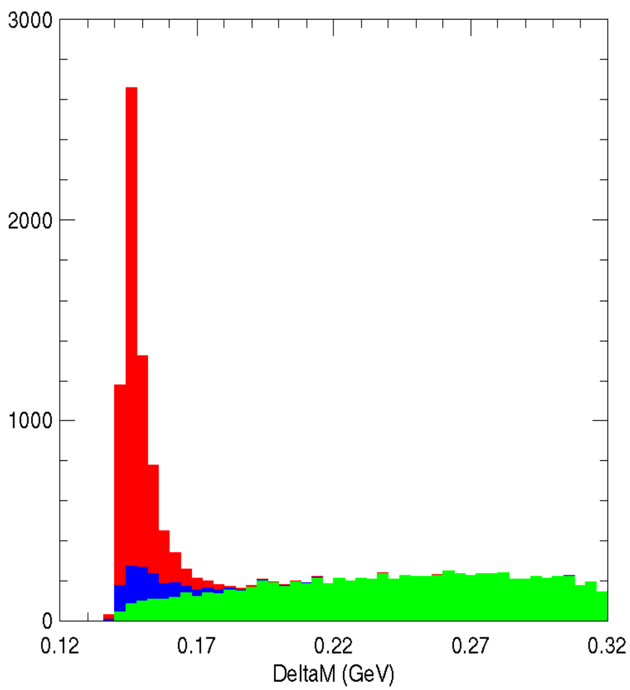
- Hadron ID: RICH + dE/dx
- $D^{*+} \to D^0 \pi_s^+$ where $D^0 \to K^- \pi^+$
- typical efficiency and fake rates:



- overall fake rate: $\sim 2\%$

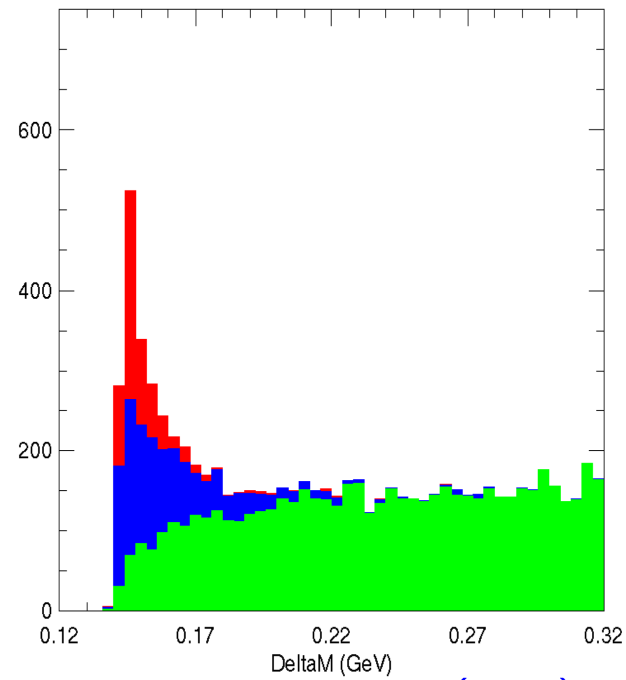
Backgrounds for $D^0 \to K^- \ell^+ \nu$ and $D^0 \to \pi^- \ell^+ \nu$

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



  - ◇ peaking background (blue); dominated by $D^0 \to K^{*-} \ell^+ \nu$
  - ◇ non-peaking background(green);
- signal (red).

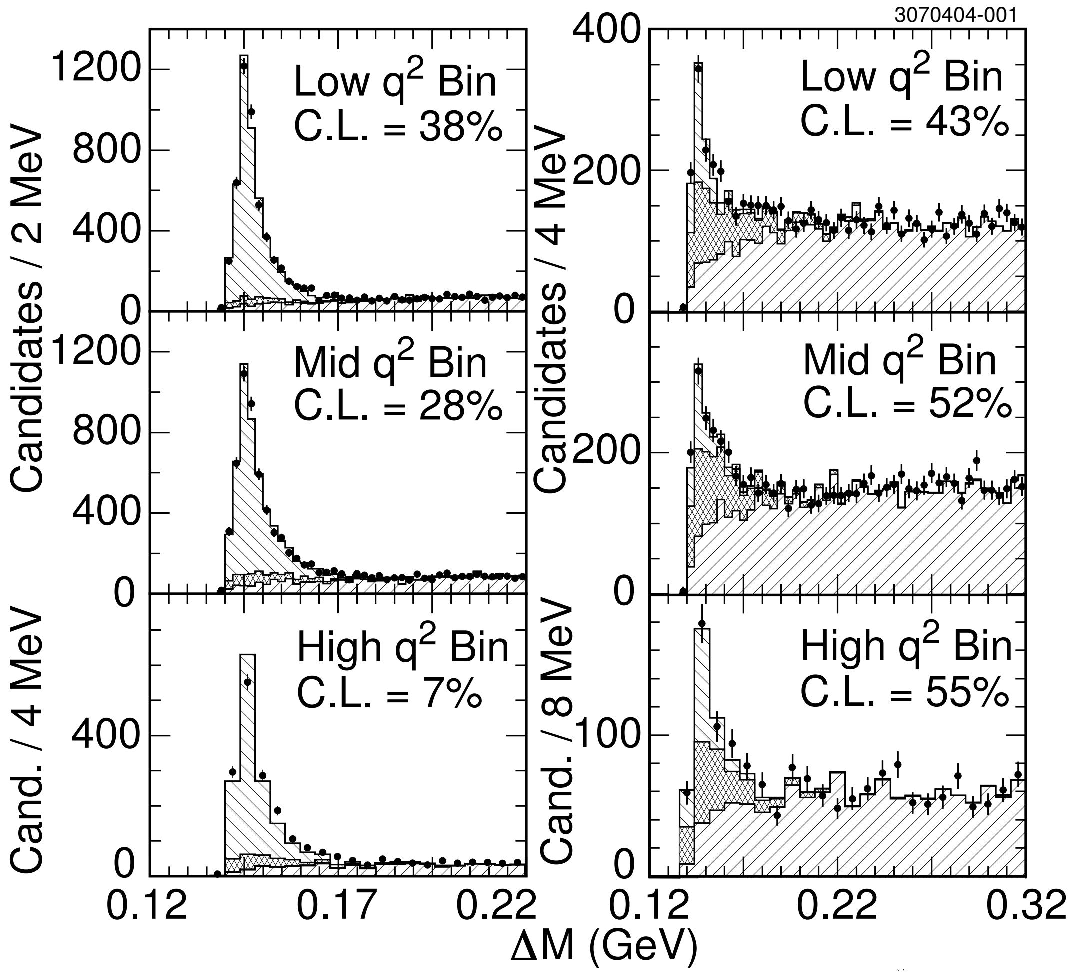
- Backgrounds for $D^0 \to \pi^- \ell^+ \nu$



  - ◇ peaking background (blue): real π_s^+ with random D^0 (44%); $D^0 \to K^* \ell \nu$ (32%), $K \ell \nu$ (8%), $\rho \ell \nu$ (9%);
  - ◇ non-peaking background (green);
- signal (red).

Fits to ΔM

- Fits to data (8 fb^{-1}): $D^0 \to K^- e^+ \nu$ (left), $D^0 \to \pi^- e^+ \nu$ (right)

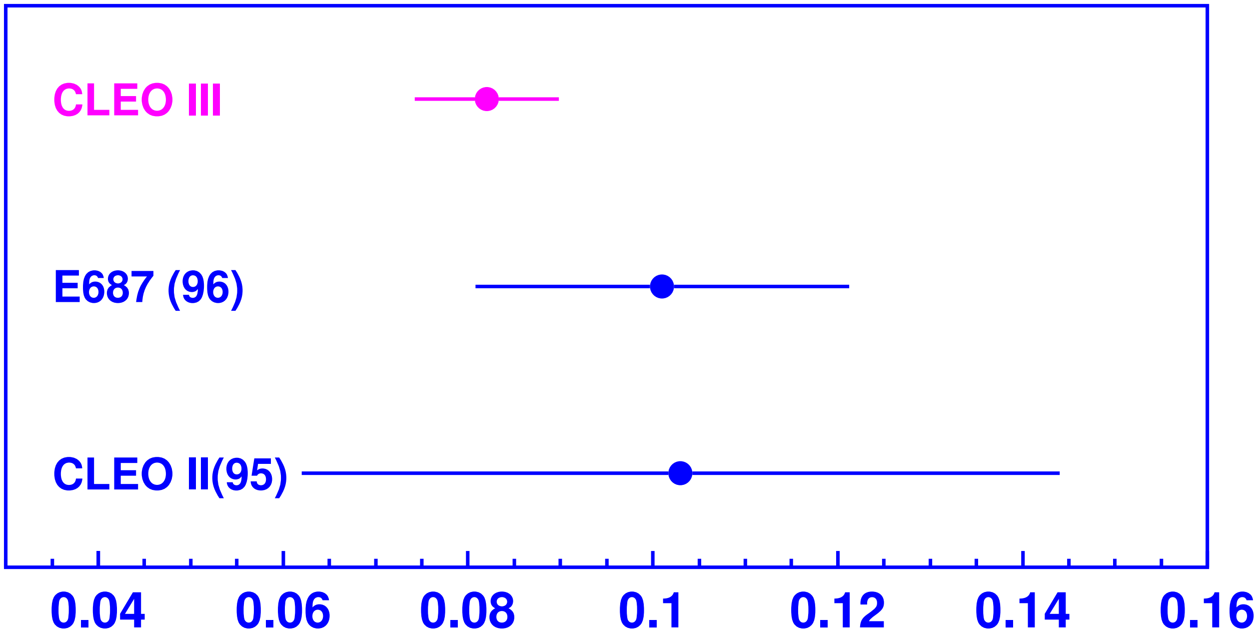


- Fits to $D^0 \to K^- \mu^+ \nu$ and $D^0 \to \pi^- \mu^+ \nu$ ($\sim$1/4) give consistent results

$$R = \frac{\mathcal{B}(D^0 \to \pi^- \ell^+ \nu)}{\mathcal{B}(D^0 \to K^- \ell^+ \nu)}$$

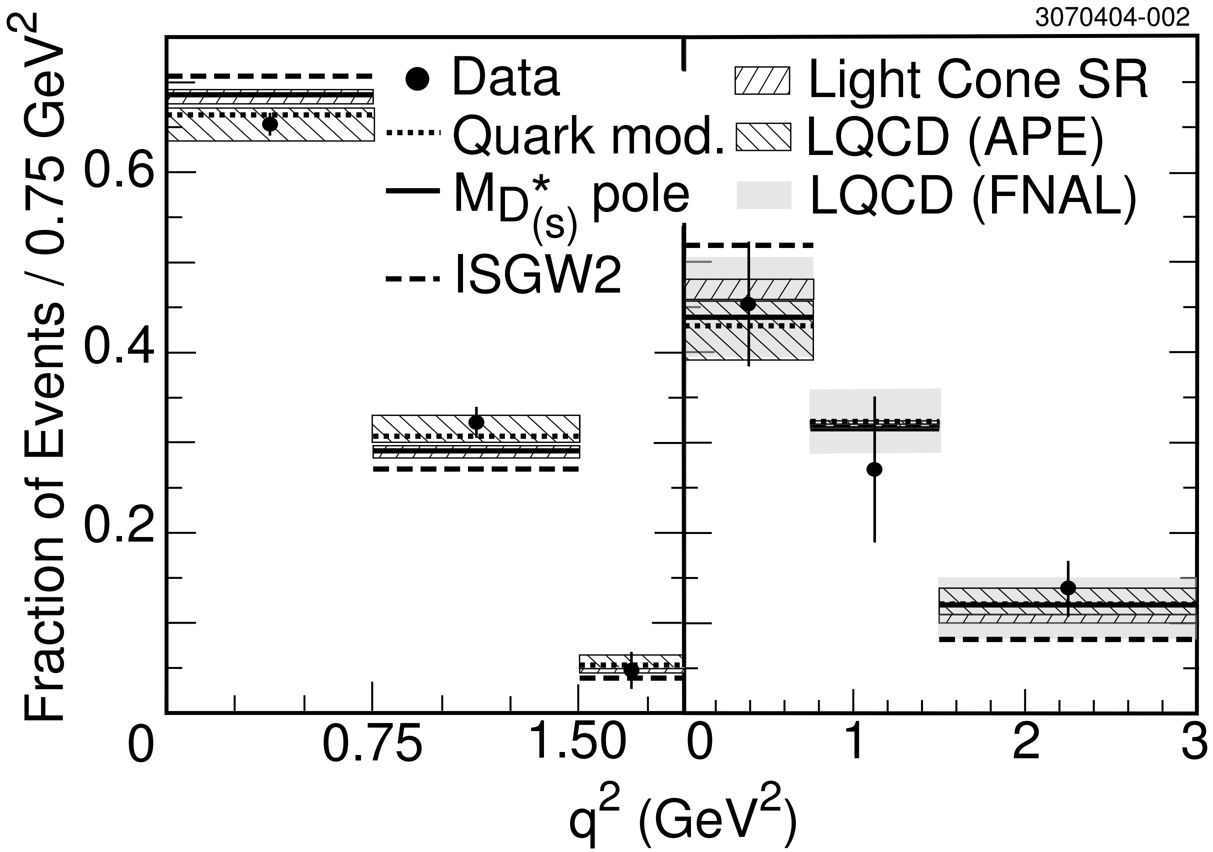
- $R_e = 0.085 \pm 0.006 \pm 0.006$
- $R_\mu = 0.075 \pm 0.012 \pm 0.006$
- combine e and μ modes after correction for μ phase space
  $R = 0.082 \pm 0.006 \pm 0.005$

  systematics dominated by the peaking backgrounds.



Fits to $\frac{d\Gamma}{\Gamma dq^2}$

- Fits to $\frac{d\Gamma}{\Gamma dq^2}$: $D^0 \to K^- \ell^+ \nu$ (left), $D^0 \to \pi^- \ell^+ \nu$ (right) (e/μ combined)



- First study of the $D^0 \to \pi^- \ell^+ \nu$ form factors
- $D^0 \to K^- \ell^+ \nu$ doesn't favor ISGW2 model

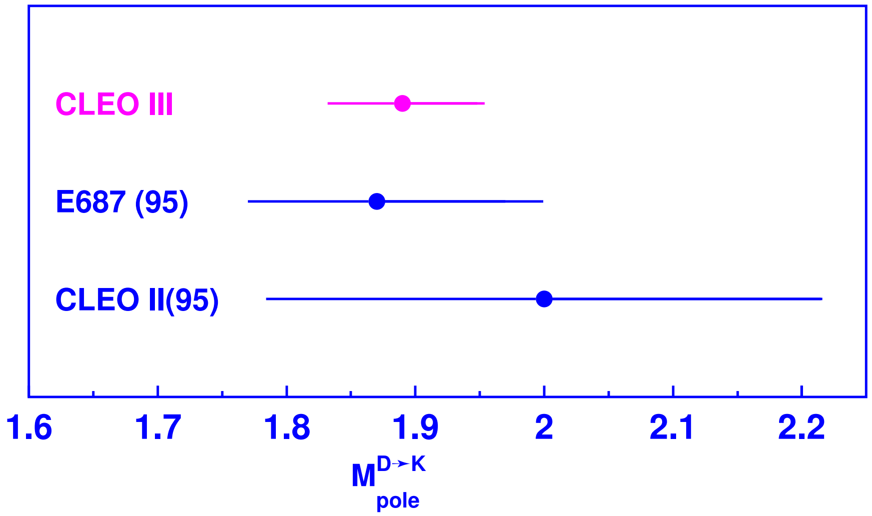
Form factors (I)

- Simple pole:

$$f_+(q^2) = \frac{f_+(0)}{1 - q^2/M^2_{pole}}$$

effective pole mass M_{pole}

- we have:
$M^{D\to\pi}_{\rm pole} = 1.86^{+0.10+0.07}_{-0.06-0.03}$ GeV, consistent with $M_{D^*} = 2.01$ GeV
$M^{D\to K}_{\rm pole} = 1.89 \pm 0.05^{+0.04}_{-0.03}$ GeV, away from $M_{D_s^*} = 2.112$ GeV



Form factors (II)

- Modified pole:

$$f_+(q^2) = \frac{f_+(0)}{(1 - q^2/M^2_{D^*_{(s)}})(1 - \alpha q^2/M^2_{D^*_{(s)}})}$$

lowest pole mass $M_{D^*_{(s)}}$ and higher resonance poles with $M_{D^*_{(s)}}/\sqrt{\alpha}$

- We have:

parameter α	CLEO III	quenched LQCD	unquenched LQCD
$\alpha^{D\to\pi}$	$0.37^{+0.20}_{-0.31} \pm 0.15$	$0.36 \pm 0.16^{+0.00}_{-0.07}$	$0.32 \pm 0.06\ (stat.)$
$\alpha^{D\to K}$	$0.36 \pm 0.10^{+0.03}_{-0.07}$	$0.43 \pm 0.12^{+0.00}_{-0.02}$	$0.35 \pm 0.06\ (stat.)$

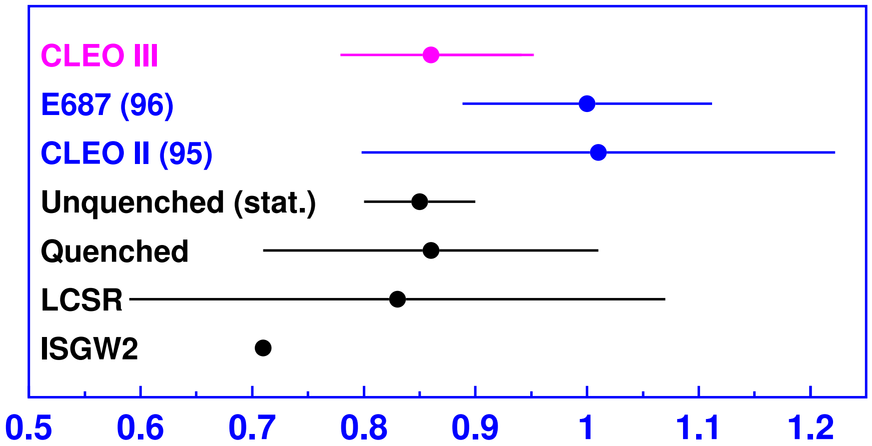
Ratio of $f_+(0)$

- Combined ratio:

$$\frac{|f_+^\pi(0)|^2|V_{cd}|^2}{|f_+^K(0)|^2|V_{cs}|^2} = 0.038^{+0.006+0.005}_{-0.007-0.003}$$

- Using $|V_{cd}/V_{cs}|^2 = 0.052 \pm 0.001$, we have

$$\frac{f_+^\pi(0)}{f_+^K(0)} = 0.86 \pm 0.07^{+0.06}_{-0.04} \pm 0.01$$



Summary

- Improved R by of factor of two

$$\frac{\mathcal{B}(D^0 \to \pi^- \ell^+ \nu)}{\mathcal{B}(D^0 \to K^- \ell^+ \nu)} = 0.082 \pm 0.006 \pm 0.005$$

PDG: $(10.1 \pm 1.8)\%$

- Model independent

$$\frac{|f_+^\pi(0)|^2 |V_{cd}|^2}{|f_+^K(0)|^2 |V_{cs}|^2} = 0.038^{+0.006+0.005}_{-0.007-0.003}$$

- Improved the $D^0 \to K^- \ell^+ \nu$ form factors;
- First determination of the $D^0 \to \pi^- \ell^+ \nu$ form factors.
- CLEO Collaboration, hep-ex/0407035, submitted to PRL.
- More CLEO-c results will be presented at the conference.