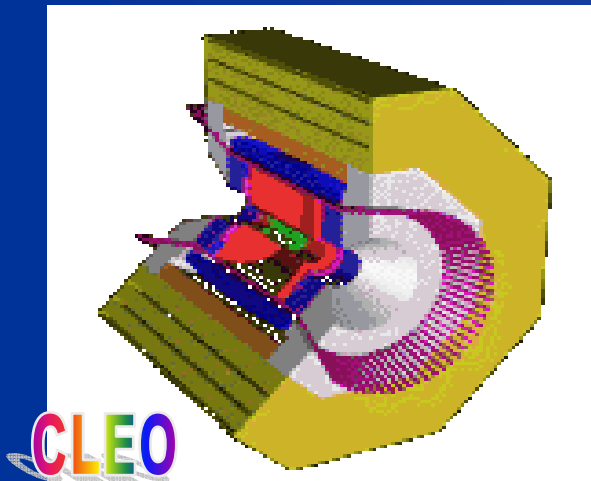


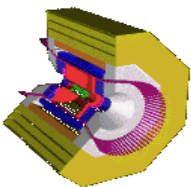
# $D^+ \rightarrow \mu^+ \nu$ and $f_D$ from $281 \text{ pb}^{-1}$ at $\psi(3770)$ with CLEO-c

Yongsheng Gao

Southern Methodist University  
(CLEO Collaboration)

HEP2005, Lisbon, Jul. 21 – 27, 2005





# Outline

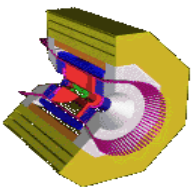


## Introduction

**$D^+ \rightarrow \mu^+ \nu$  and  $f_{D^+}$  (281 pb<sup>-1</sup> at  $\psi(3770)$ )**

- Analysis Techniques
- Fully reconstructed  $D^-$  tags
- $D^+ \rightarrow \mu^+ \nu$  Reconstruction
- Background suppression
- Results

## Summary



# Flavor Physics and CLEO-c



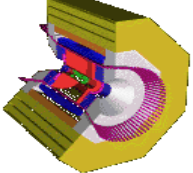
$$\mathbf{V}_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

## Test the SM and Search for New Physics:

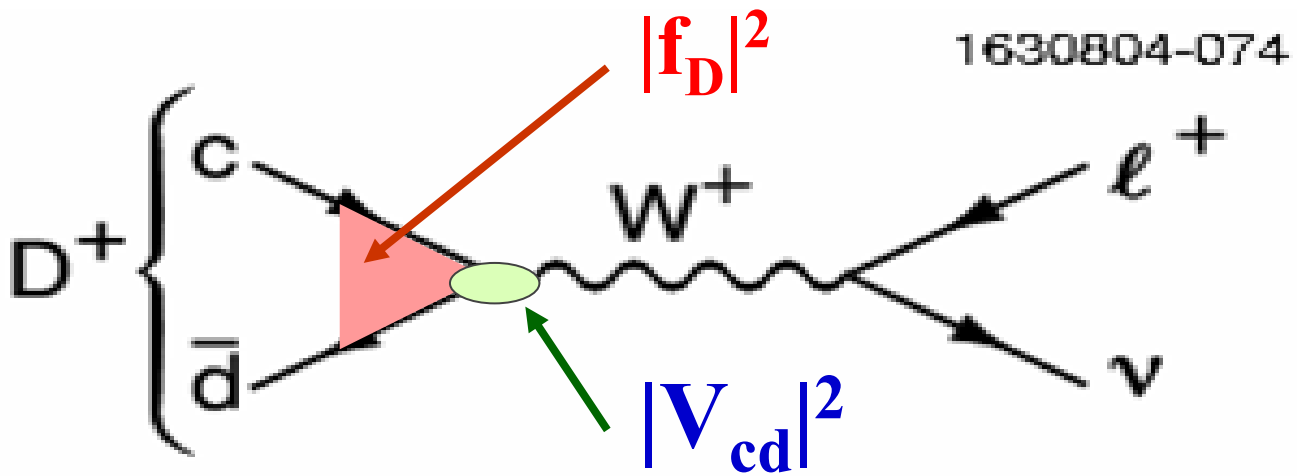
- Precise measurements/over constrain of CKM
- One limiting factor: syst. error of non-pert. QCD

## CLEO-c Physics at $\Psi(3770)$ :

- $f_{D^*}$ ,  $f_{D_s^*}$ : Validate Lattice QCD and improve  $f_B$
- Semileptonic D decay: Form factors and  $V_{cd}$ ,  $V_{cs}$

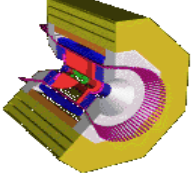


# Leptonic $D^+ \rightarrow \mu^+ \nu$ Decay

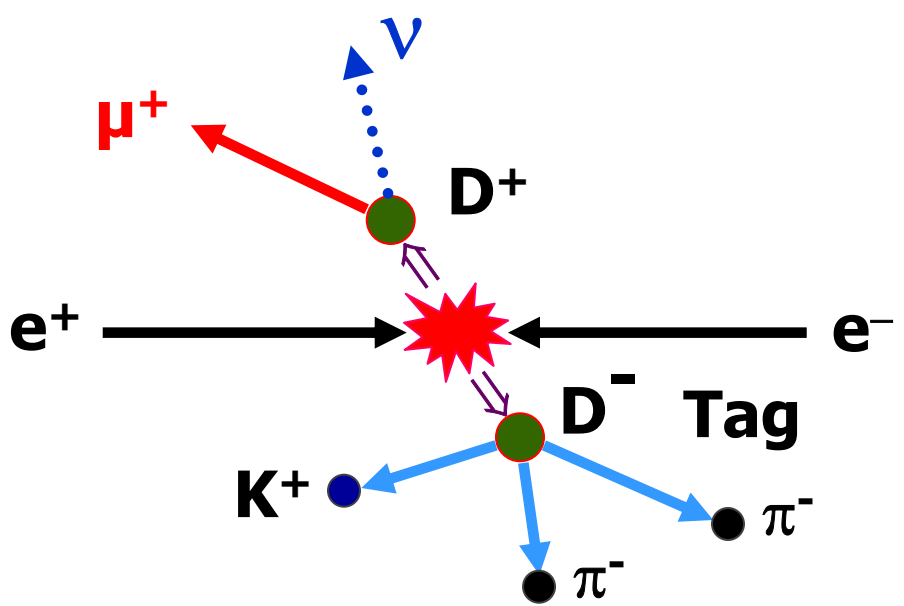


$$\Gamma(D^+ \rightarrow l^+ \nu) = \frac{G_F^2}{8\pi} f_{D^+}^2 m_l^2 M_{D^+} \left(1 - \frac{m_l^2}{M_{D^+}^2}\right)^2 |V_{cd}|^2$$

**Compare theoretical calculations of  $f_D$  to experimental measurement to gain confidence in theory's ability to predict  $f_B$**



# $\psi(3770)$ Analysis Techniques



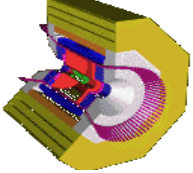
## The MARK III Method

Fully reconstruct 1<sup>st</sup> D  
 “the tag”, then analyze  
 decay of 2<sup>nd</sup> D to extract  
 exclusive or inclusive  
 properties.

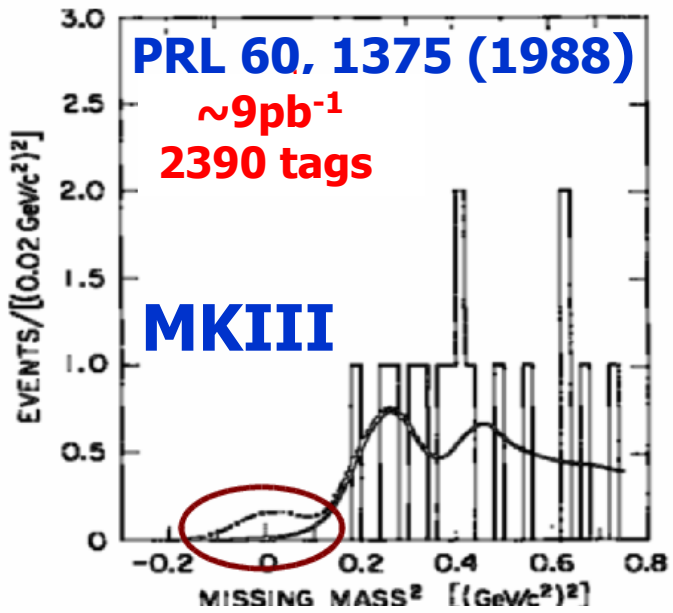
$$\Delta E = E(D) - E_{\text{beam}}$$

$$M_{BC} = \sqrt{E_{\text{beam}}^2 - |p(D)|^2}$$

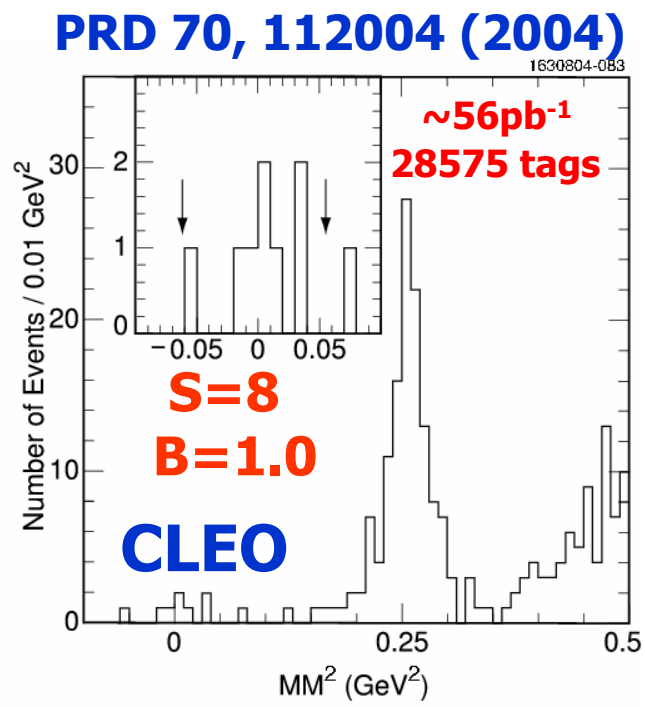
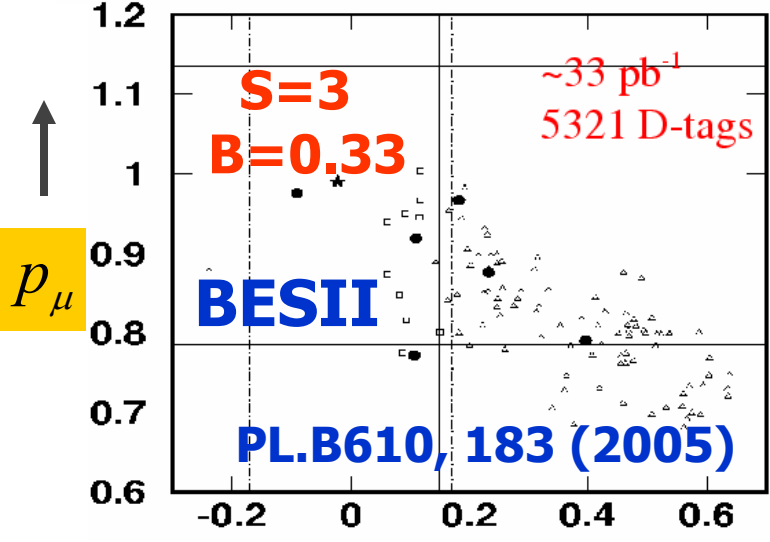
- $\psi(3770) \sim D\bar{D}$  threshold
- No extra fragmentation = simpler geometry / combination
- Clean neutrino reconstruction
- High tagging efficiency at 20% of all D's produced.



# $f_{D^+}$ from Absolute $\text{Br}(D^+ \rightarrow \mu^+ \nu)$

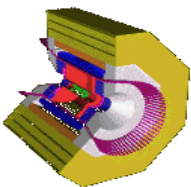


	$B(D^+ \rightarrow \mu \nu) \times 10^{-4}$	$f_D$ MeV
MkIII	$< 7.2$	$< 290$
BESII	$12.2_{-53}^{+11.1} \pm 0.11$	$371_{-119}^{+129} \pm 25$
<b>CLEO</b>	<b><math>3.5 \pm 1.4 \pm 0.6</math></b>	<b><math>202 \pm 41 \pm 17</math></b>

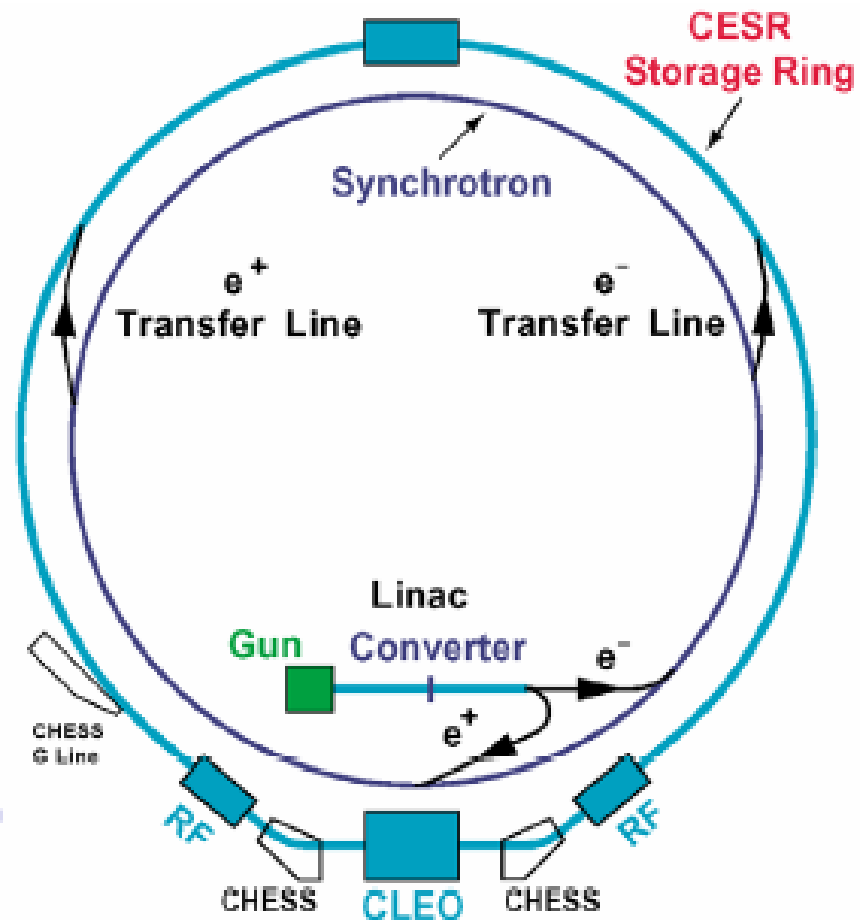


**First Observation**



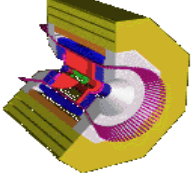


# CESR-c



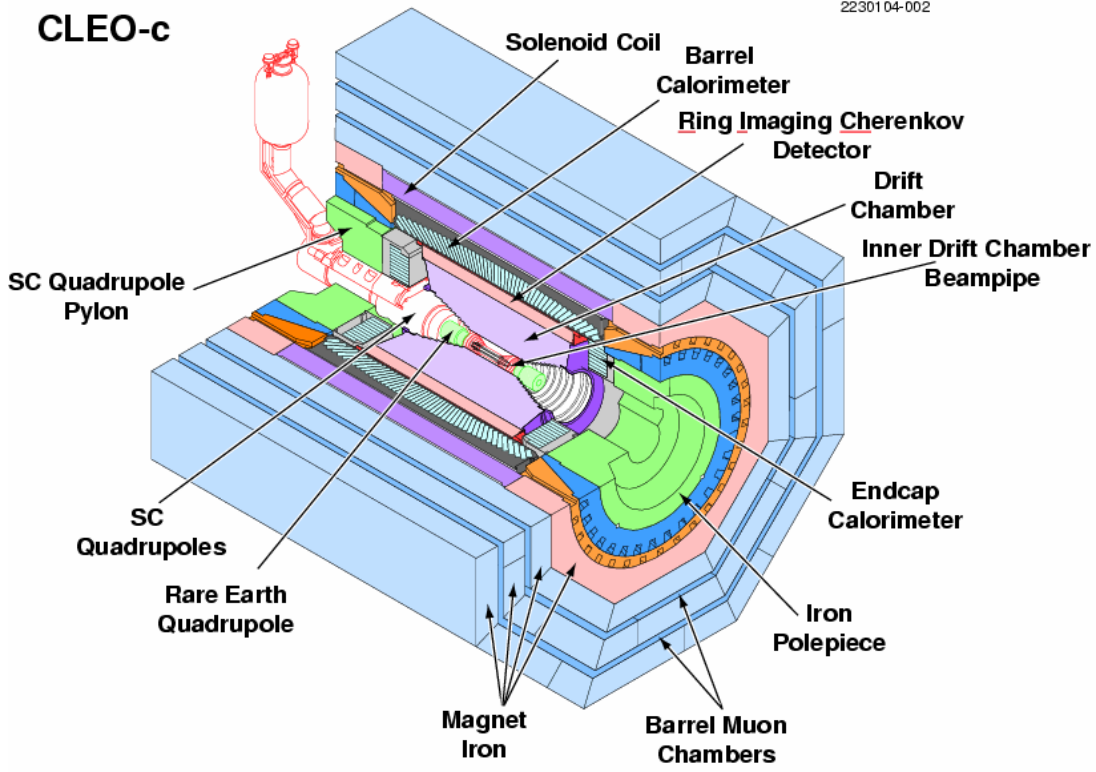
$$E_{\text{beam}} = 1.5 - 5.6 \text{ GeV}$$

# CLEO-c Detector & Data

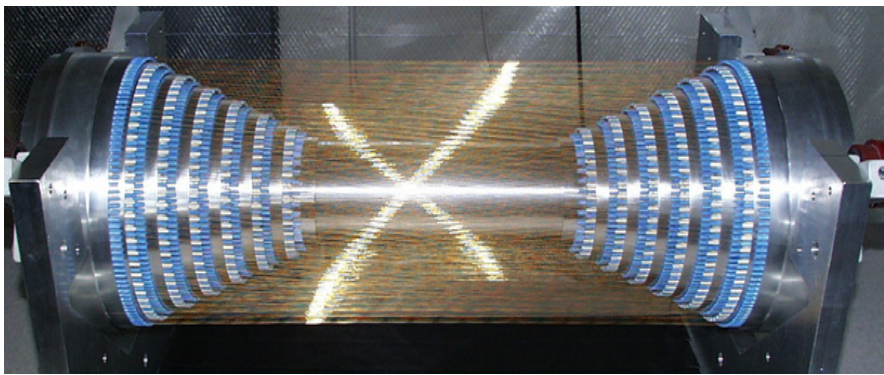


CLEO-c

2230104-002

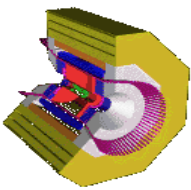


- New inner drift chamber replaced old silicon vertex
- 1T B field (old 1.5 T)
- Track (93% of  $4\pi$ ):  $\sigma = 0.6\% @ 1 \text{ GeV}$
- PID: Rich (80% of  $4\pi$ ),  $dE/dx$ , EM calorimeter, muon ( $> 1\text{GeV}$ )
- $E_\gamma$ :  $\sigma = 2.2\% @ 1 \text{ GeV}$ ,  
5% @ 100MeV.



**CLEO-c  $\cong$  CLEO III**  
**281 pb<sup>-1</sup> at  $\psi(3770)$**



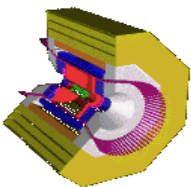


# $\psi(3770)$ analyses at CLEO-c



## $D^+ \rightarrow \mu^+ \nu$ and decay constant $f_{D^+}$ at CLEO-c

- High resolution detector with tuned MC
- Simple low multiplicity events
- Hermeticity of the detector
- $dE/dx$  ( $\pi$ ,  $K$ ,  $p$ ,  $e$ )
- RICH detector (K threshold  $\sim 550$  MeV)
- $dE/dx$  + RICH: Hadron ID for D tagging
- CsI Calorimeter (electron, muon identification)
- Beam energy  $\sigma_{E_{cm}} = 2.3$  MeV



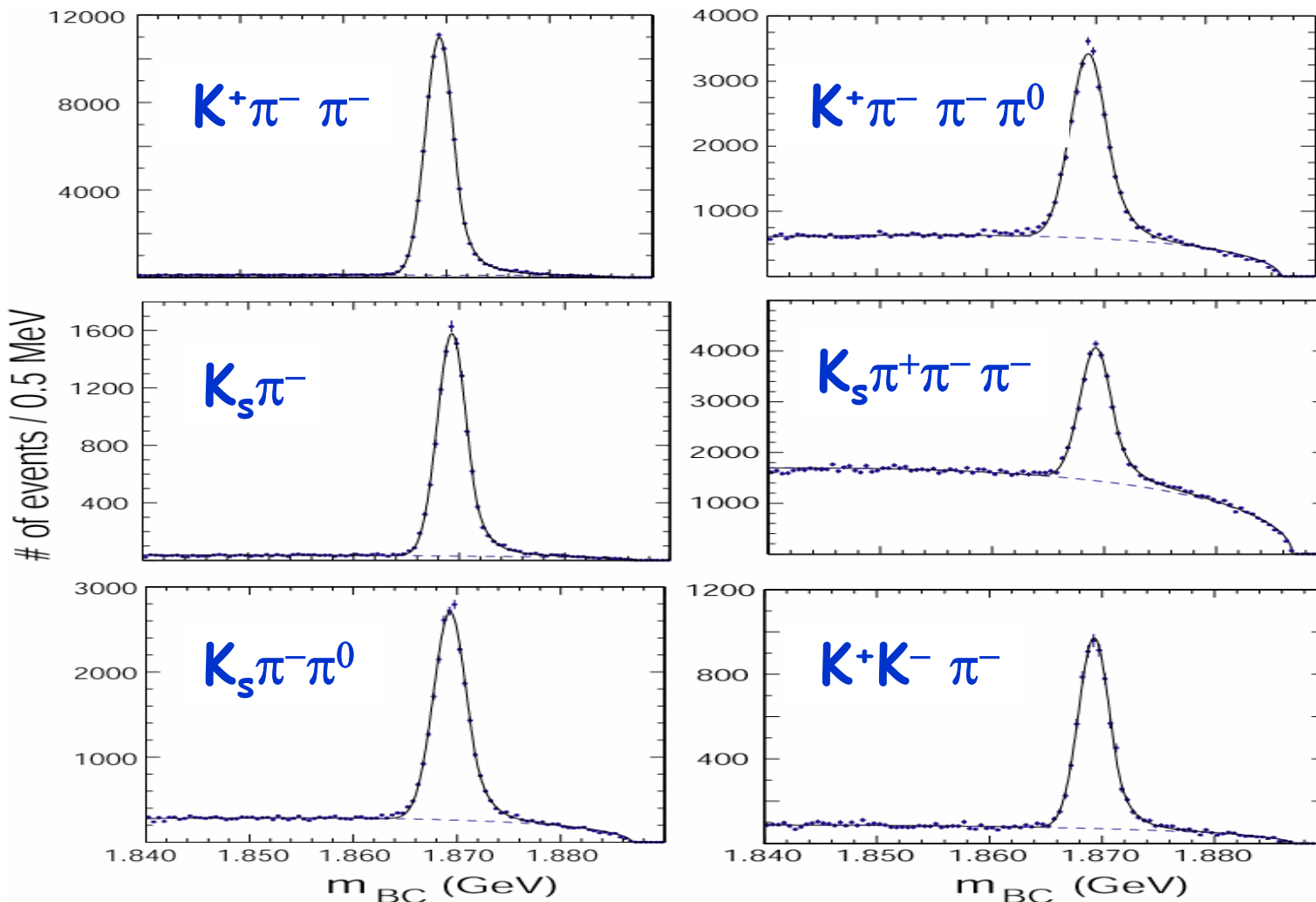
# Fully reconstructed $D^-$ tag

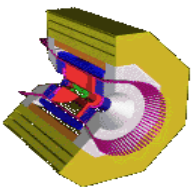


**Preliminary**

**From 281 pb-1 at  $\Psi(3770)$**

**158K fully reconstructed  $D^-$**





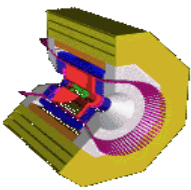
# Fully reconstructed $D^-$ tag



Mode	Signal	Background
$K^+ \pi^- \pi^-$	$77387 \pm 281$	1868
$K^+ \pi^- \pi^- \pi^0$	$24850 \pm 214$	12825
$K_S \pi^-$	$11162 \pm 136$	514
$K_S \pi^- \pi^- \pi^+$	$18176 \pm 255$	8976
$K_S \pi^- \pi^0$	$20244 \pm 170$	5223
$K^+ K^- \pi^-$	$6535 \pm 95$	1271
Sum	$158354 \pm 496$	30677

Preliminary

**Reconstruction Efficiency: (20 – 55)%**



# Reconstruct $D^+ \rightarrow \mu^+ \nu$



**Neutrino  $MM^2$  to discriminate signal and backgrounds:**

$$MM^2 = (E_{beam} - E_{\mu})^2 - (-\vec{P}_D - \vec{P}_{\mu})^2$$

**Signal peaks at  $MM^2 = 0$**

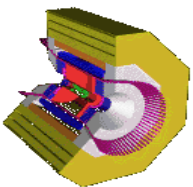
**Additional cuts to suppress background:**

- **No additional charged tracks from event vertex**
- **Largest unmatched shower energy less than 0.25 GeV, to suppress  $D^+ \rightarrow \pi^+ \pi^0$**
- **Muon candidate consistent with minimum ionizing particle ( $E_{cal} < 300$  MeV in EM cal)**

**$\sim 67\%$  efficient for  $D^+ \rightarrow \mu^+ \nu$**

**Most systematic errors are determined using DATA**

**Detailed background studies based on MC+DATA**

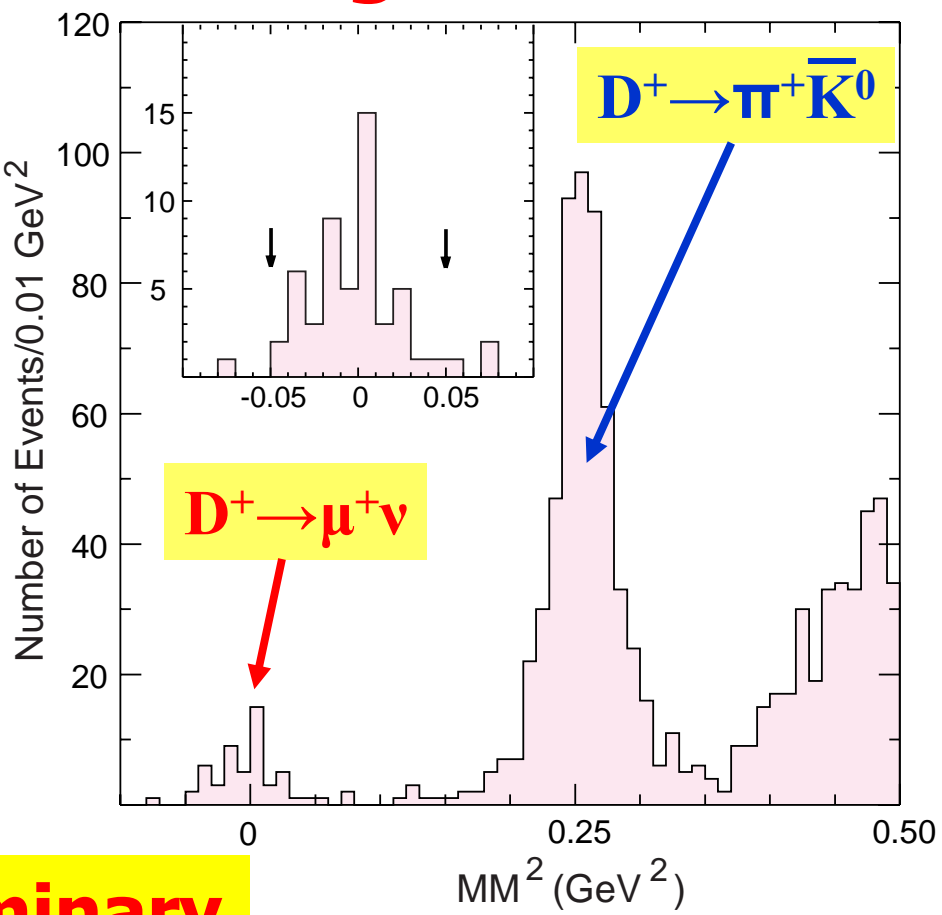
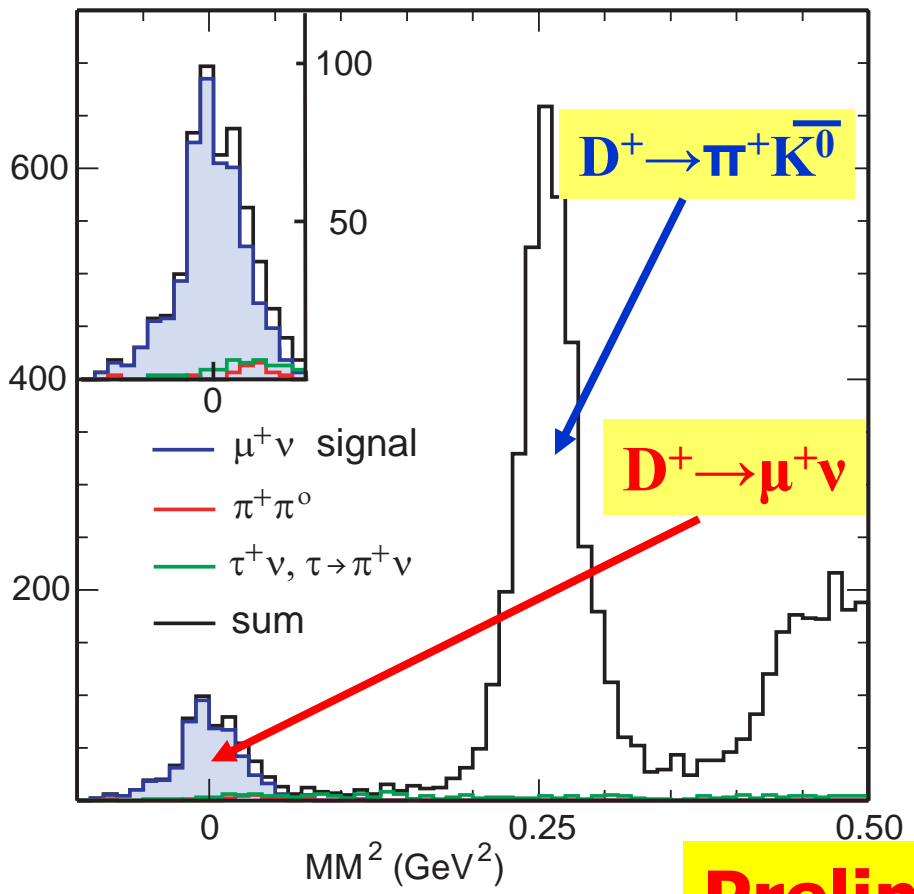


# $D^+ \rightarrow \mu^+ \nu$ from CLEO-c Data



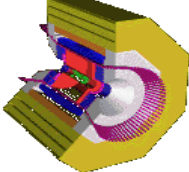
MC Expectations from 1.7 fb<sup>-1</sup>, 6 x data

281 pb<sup>-1</sup> at  $\psi(3770)$   
50 signal events



Preliminary





# Br(D<sup>+</sup> → l<sup>+</sup>ν) & f<sub>D<sup>+</sup></sub> from CLEO-c



## Backgrounds

Mode	$\mathcal{B}(\%)$	# Events
$\pi^+\pi^0$	$0.13 \pm 0.02$	$1.40 \pm 0.18$
$\bar{K}^0\pi^+$	$2.77 \pm 0.18$	$0.44 \pm 0.44$
$\tau^+\nu$ ( $\tau \rightarrow \pi^+\nu$ )	$2.65 * \mathcal{B}(D^+ \rightarrow \mu^+\nu)$	$1.08 \pm 0.15$
Continuum $D^0D^0 +$ other $D^+D^-$	-	0; < 0.8 events @ 32% CL
Total	-	$2.92 \pm 0.50^{+0.8}_{-0}$

**Preliminary**

Efficiencies & BKG well understood: from data

$$\mathbf{Br(D^+ \rightarrow \mu^+\nu) = (4.45 \pm 0.67^{+0.29}_{-0.36}) \times 10^{-4}}$$

$$f_{D^+} = (223 \pm 16^{+7}_{-9}) \text{ MeV}$$

No  $D^+ \rightarrow e^+\nu$  events observed:

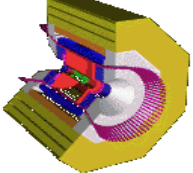
$$\mathbf{Br(D^+ \rightarrow e^+\nu) < 2.4 \times 10^{-5} @ 90\% \text{ C.L.}}$$

$$V_{us}(\text{KTeV}) = 0.225 \pm 0.0023$$

$$V_{us}(\text{NA48}) = 0.2187 \pm 0.0016(\text{exp}) \pm 0.0023(\text{th})$$

$$V_{us}(\text{NA48}) = 0.2239 \pm 0.0012(\text{exp}) \pm 0.0023(\text{th})$$

$$f_+(0)V_{us}(\text{KLOE}) = 0.216 \pm 0.001(\text{exp}) \text{ (Ke3)}$$



# Current Experiment & Theory



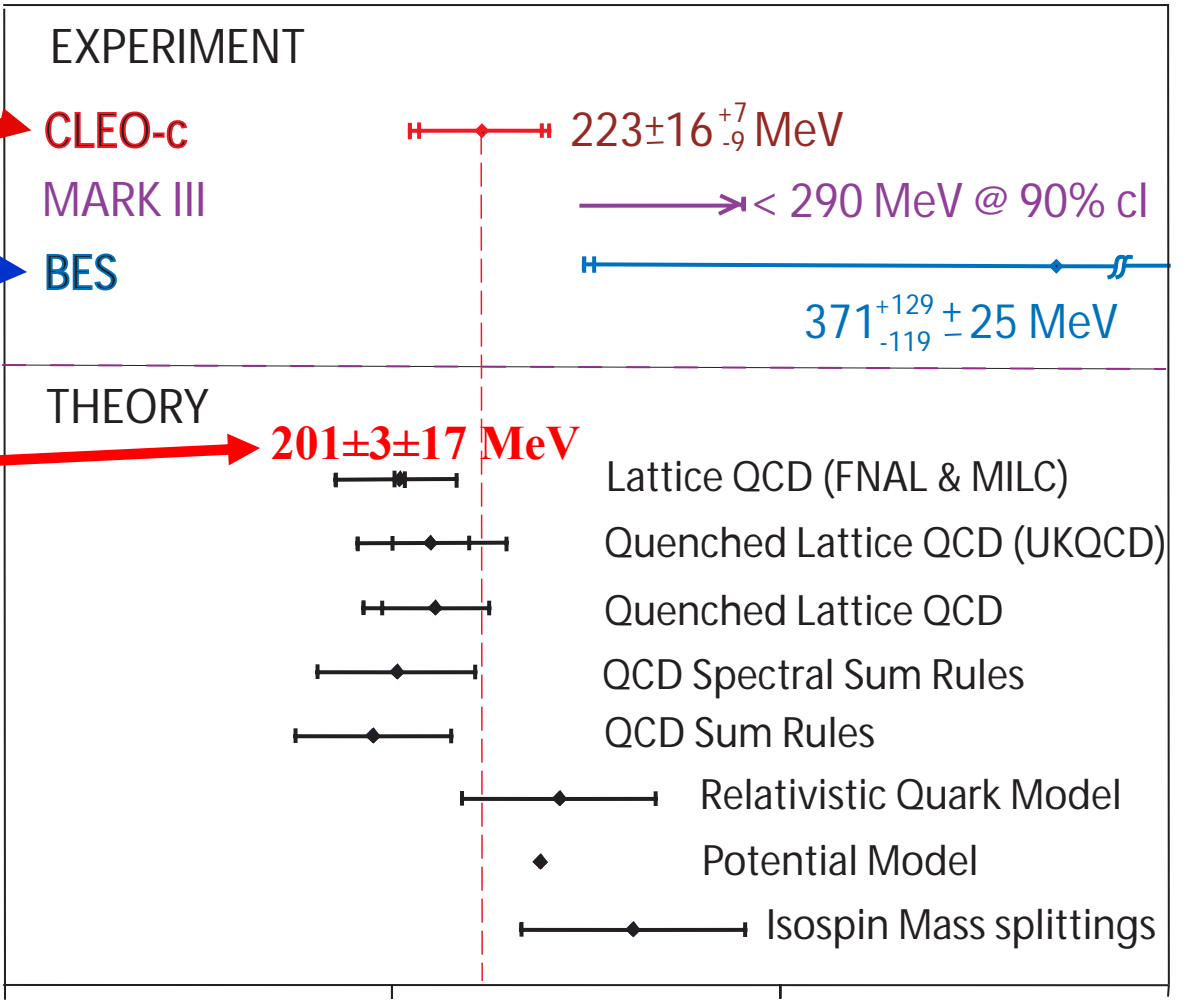
This measurement

BES measurement  
( $2.67 \pm 1.74$  evts)

Fermilab-MILC-HPQCD  
(hep-lat0506030)

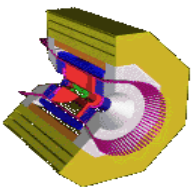
Chiu et al. hep-ph/0506266  
 $f_D = (235 \pm 8 \pm 14)$  MeV

CP-PACS:  
 $f_D = (202 \pm 12^{+20}_{-25})$  MeV



c.f. Artuso, Stewart's LP05 talk

$f_{D^+}$  (MeV)



# Br(D<sup>+</sup> → l<sup>+</sup>ν) & f<sub>D<sup>+</sup></sub> from CLEO-c



**Preliminary from 281 pb<sup>-1</sup> at ψ(3770):**

**(CLEO CONF 05-5)**

**158,354 ± 496 fully reconstructed D<sup>-</sup> tags**

**47.1 ± 7.1<sup>+2.9</sup><sub>-3.7</sub> D<sup>+</sup> → μ<sup>+</sup>ν evts observed**

$$\text{Br}(D^+ \rightarrow \mu^+\nu) = (4.45 \pm 0.67^{+0.29}_{-0.36}) \times 10^{-4}$$

$$f_{D^+} = 223 \pm 16^{+7}_{-9} \text{ MeV}$$

$$\text{Br}(D^+ \rightarrow e^+\nu) < 2.4 \times 10^{-5} \text{ @ 90\% C.L.}$$