

First Results from CLEO-c @ $\sqrt{s} = \Psi(3770)$

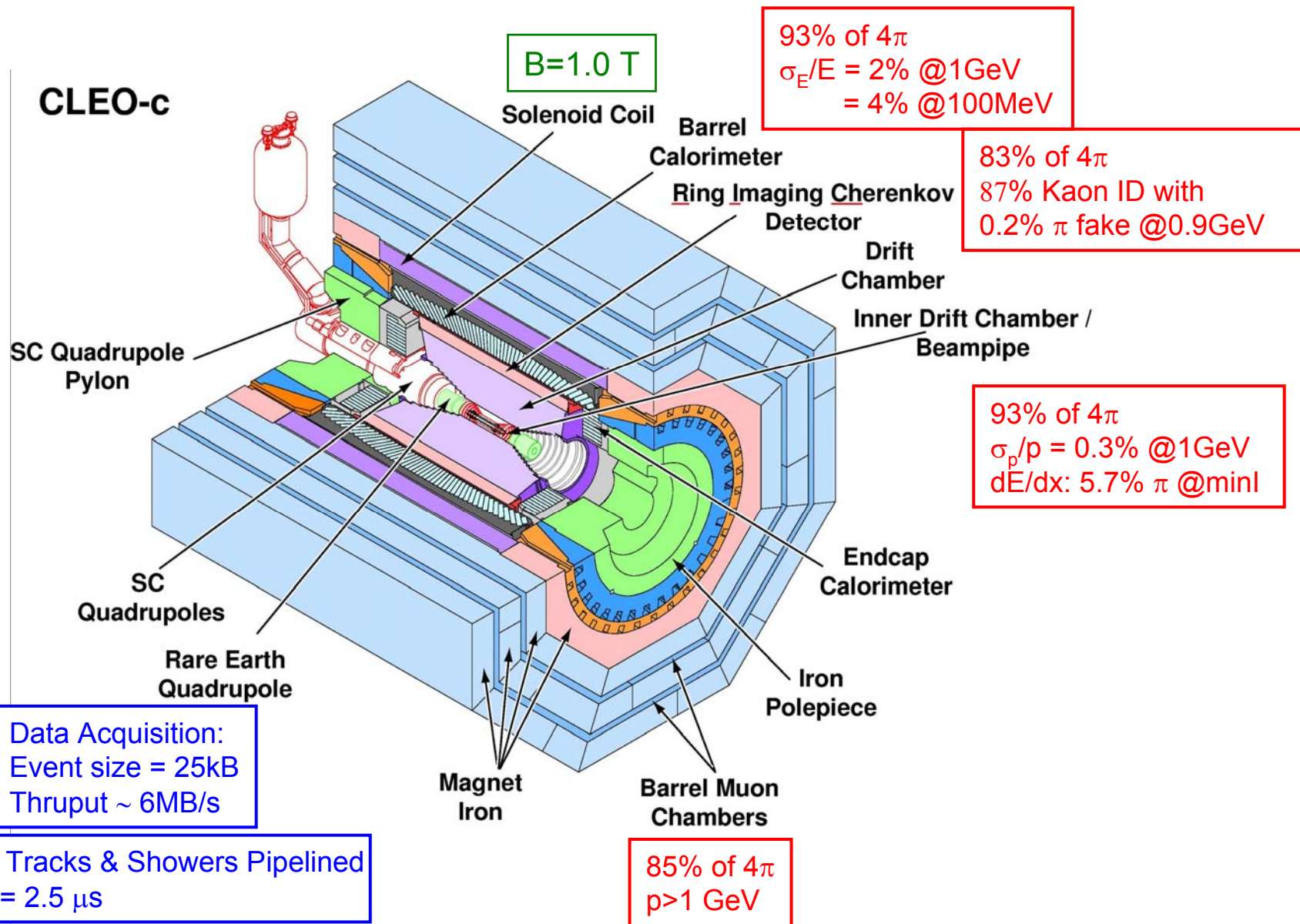
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CLEO Collaboration

- $D^+ \rightarrow \mu^+ \nu_\mu$ Decays
- Absolute $Br(D \rightarrow \text{hadrons})$
- $\sigma(e^+e^- \rightarrow D\bar{D})$
- CLEO-c Outlook

CLEO-c Detector



Leptonic Decays: $D^+ \rightarrow \mu^+ \nu_\mu$



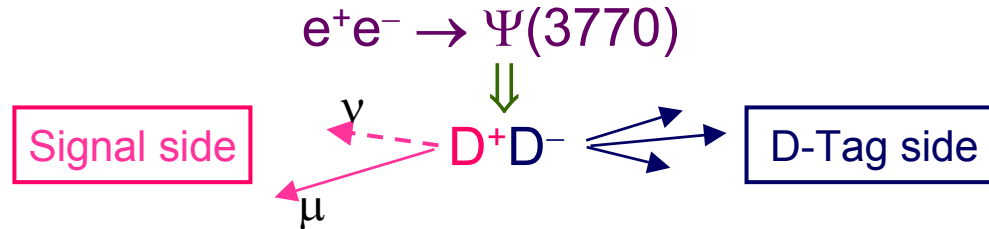
$$Br(D_q \rightarrow l\nu) = \frac{G_F^2}{8\pi} m_{D_q} m_l^2 \left(1 - \frac{m_l^2}{m_{D_q}^2}\right) f_{D_q}^2 |V_{cq}|^2 \tau_{D_q}$$

Strong Physics Weak Physics

Seek to measure f_{D^+}

- f_{D^+} provides “iron post of observation” for Lattice QCD
- f_{D^+} useful for checking potential models
- “Calibrated” Lattice QCD $(f_B/f_D) + f_D \Rightarrow f_B$
- $f_B + B\text{-mixing moments} \Rightarrow |V_{td}/V_{ts}|$ precision

Single D[±] Tag



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

- 1 track from event vertex, min_l in Csl
- “small” (< 250 MeV) neutral E loss in Csl
- no reconstructed K_s

$$D^- \rightarrow K^+ \pi^- \pi^-, K^+ \pi^- \pi^- \pi^0, K_s \pi^-, K_s \pi^- \pi^- \pi^0, K_s \pi^- \pi^0$$

- $\pi^\pm/K^\pm$ ID: dE/dx + RICH
- π^0 recon: γ shower shape/location in Csl
- K_s recon: $\pi^\pm$ kinematic fit to displaced vertex

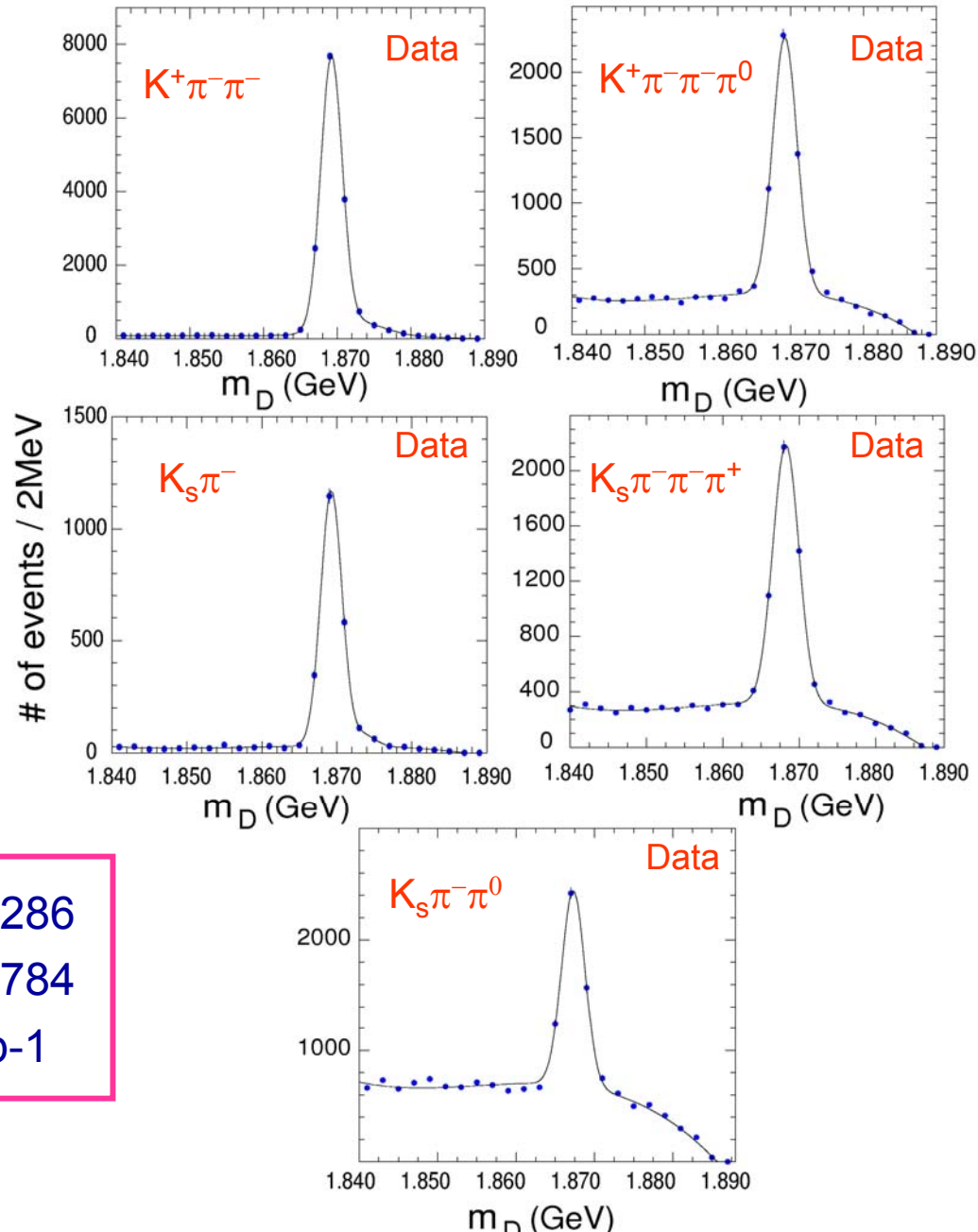
❖ Key analysis variables:

$$\triangleright M_D^2 = E_{\text{beam}}^2 - (\sum \vec{p}_i)^2$$

$$\triangleright MM^2 = (E_{\text{beam}} - E_\mu)^2 - (-\vec{p}_D - \vec{p}_\mu)^2 \quad (\text{Sensitive to } \nu\text{'s in FS})$$

$$\triangleright \int L dt = 57 \text{ pb}^{-1} @ \sqrt{s} = \Psi(3770)$$

M_D Distribution v. D Tag



S: 28575 ± 286

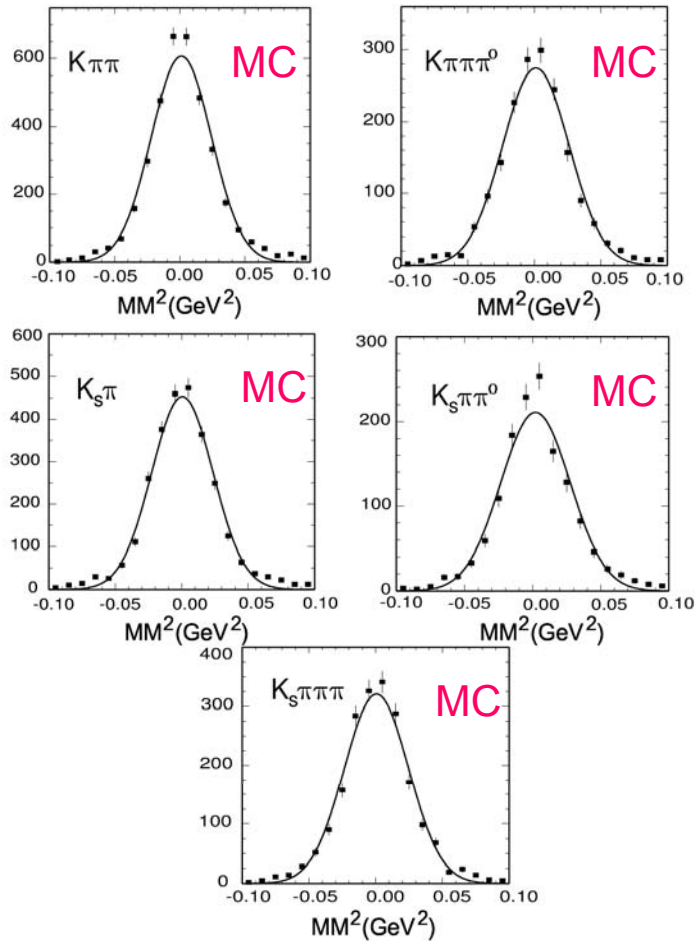
B: 8765 ± 784

$\int L dt = 57 \text{ pb}^{-1}$

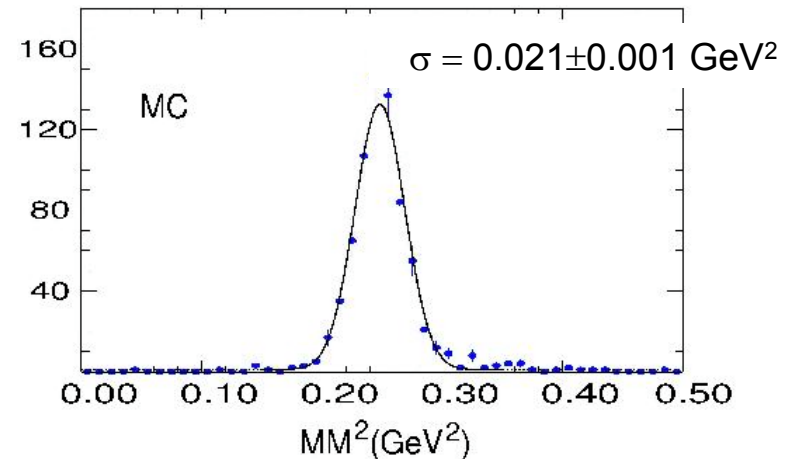
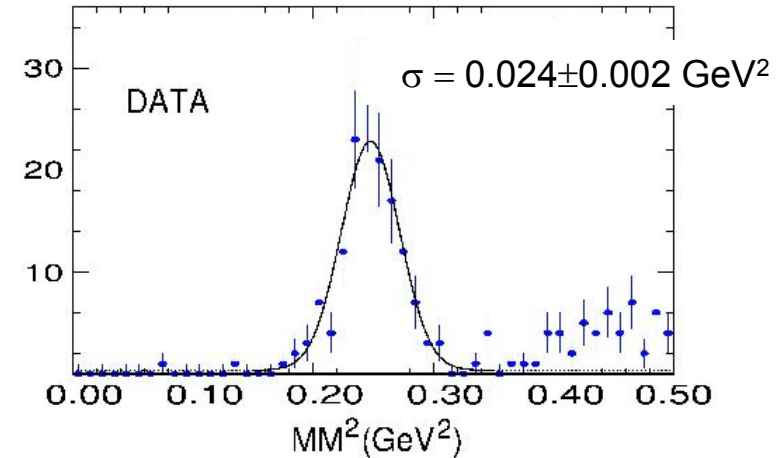
MM² Distribution v. D Tag

➤ Set search window in signal side MM2 distribution

$D^- \rightarrow K_s \pi^-$

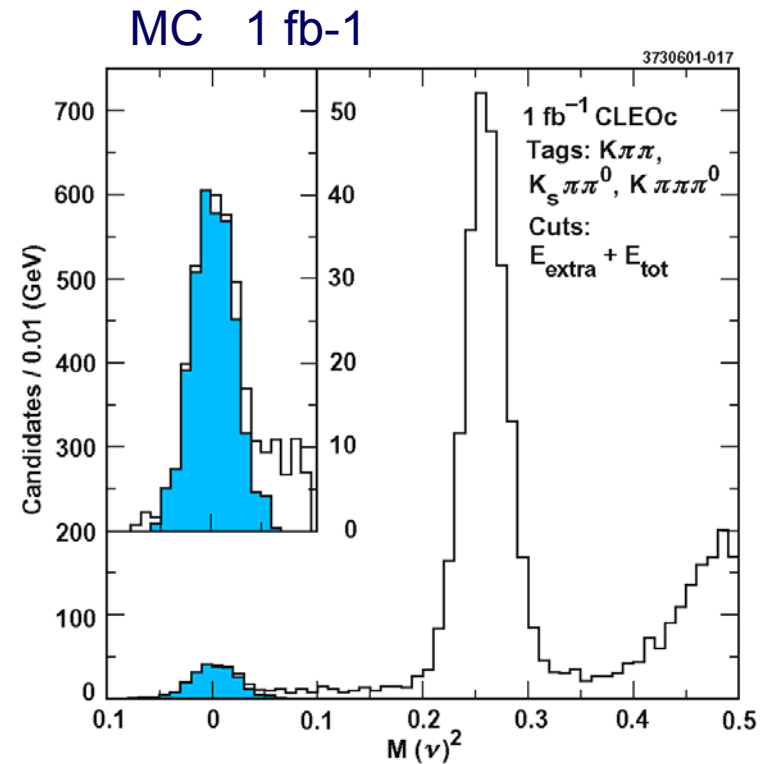
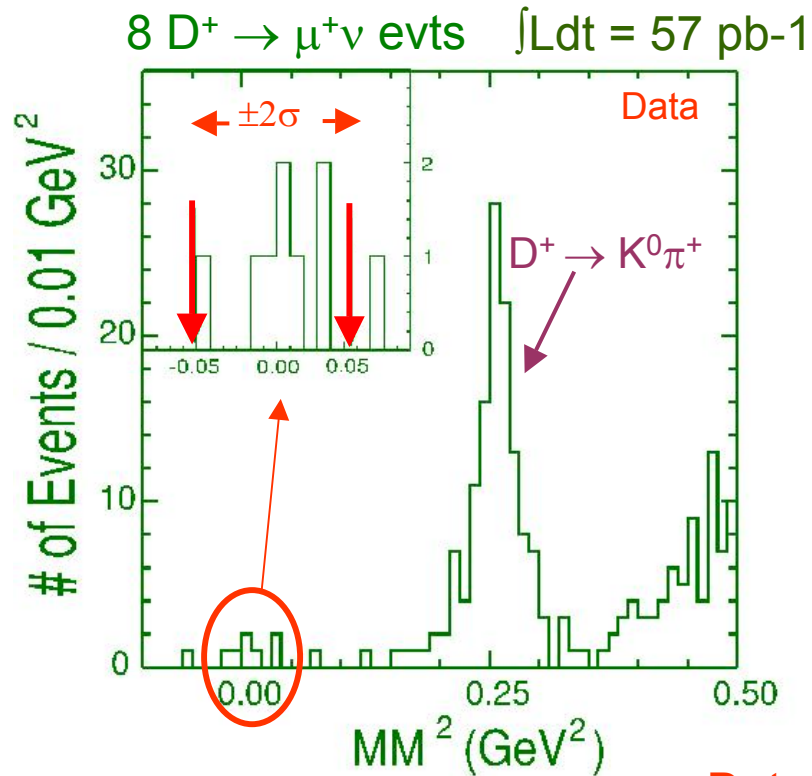


$$\sigma(\text{MM}^2) \approx 0.025 \text{ GeV}^2$$

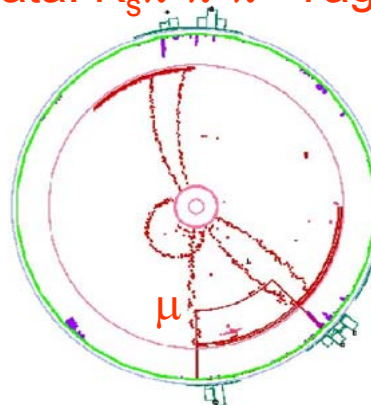


$$\sigma = (0.024/0.021) * 0.025 = 0.028 \text{ GeV}^2$$

Leptonic Decays: Signal Region



Data: $K_s\pi^-\pi^+\pi^+$ Tag



Background + Results

Background estimates via MC

♦ $D^\pm$ Background:

Mode	# of Events
$D^+ \rightarrow \pi^+ \pi^0$	0.31 ± 0.04
$D^+ \rightarrow K^0 \pi^+$	0.06 ± 0.05
$D^+ \rightarrow \tau^+ \nu$	0.36 ± 0.08
$D^+ \rightarrow \pi^0 \mu^+ \nu$	negligible

♦ $D^0 \bar{D}^0$ Background: 0.16 ± 0.16 events

♦ $e^+ e^- \rightarrow$ continuum: 0.17 ± 0.17 events

$\therefore$ O'all Bkg: 1.07 ± 1.07 events (includes systematics)

$$Br(D^+ \rightarrow \mu^+ \nu) = \frac{N_{\text{sig}}}{\epsilon * N_{\text{tag}}} \quad \& \quad \epsilon = 69.9\% \text{ for } D^+ \rightarrow \mu^+ \nu \text{ recon.}$$

$$Br(D^+ \rightarrow \mu^+ \nu) = (3.5 \pm 1.4 \pm 0.6) \times 10^{-4}$$

$$f_{D^+} = (201 \pm 41 \pm 17) \text{ MeV}$$

CLEO-c Preliminary

$$\int L dt = 57 \text{ pb}^{-1}$$

$$Br(D^+ \rightarrow \mu^+ \nu) = (12^{+9.2}_{-6.3} \text{ } ^{+1.0}_{-0.9}) \times 10^{-4}$$

$$f_{D^+} = (365^{+121}_{-113} \text{ } ^{+32}_{-28}) \text{ MeV}$$

BES: hep-ex/0406027

$$\int L dt = 17.7 \text{ pb}^{-1}$$

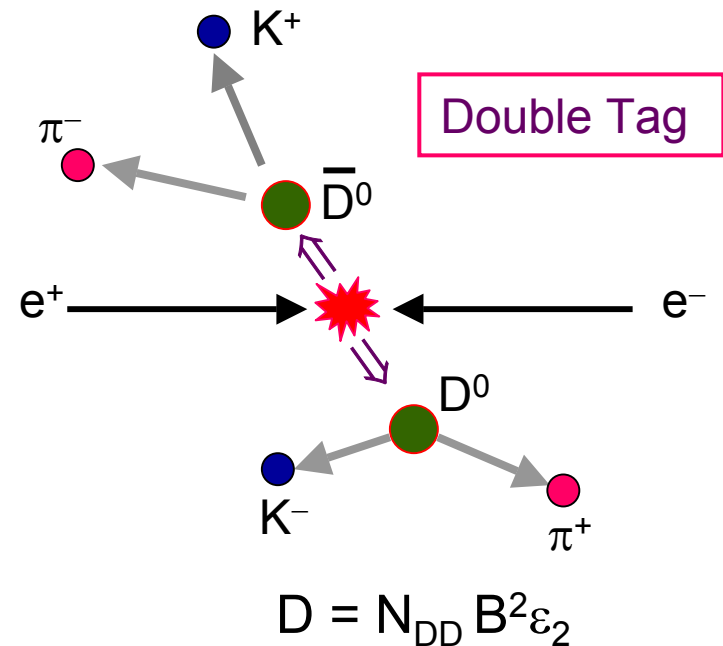
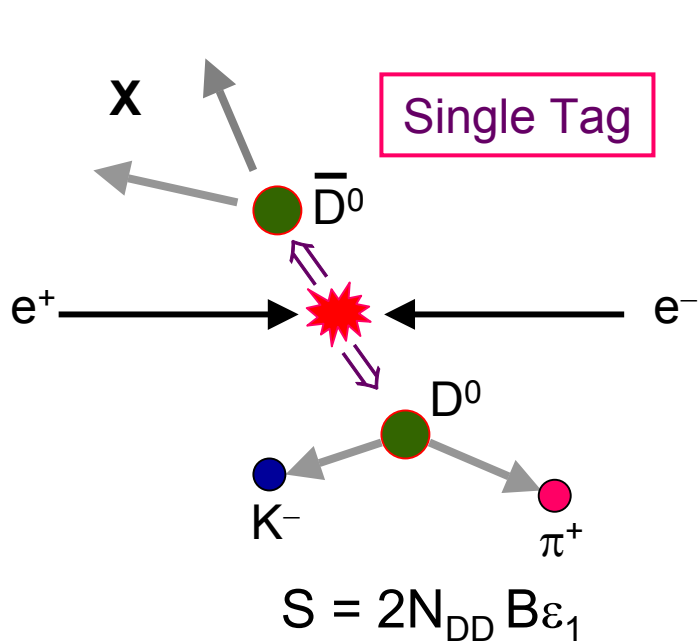
CLEO-c Physics Reach for f_D

- Large data sets planned for $\sqrt{s} = \Psi(3770)$ and $\sqrt{s} \sim 4140$ MeV

w/ 3 fb-1 & 3-gen CKM unitarity:

Decay Constant	Reaction	PDG $\delta f/f$	CLEO-c $\delta f/f$
f_{D_s}	$D_s^+ \rightarrow \mu \nu$	12%	1.9%
f_{D_s}	$D_s^+ \rightarrow \tau \nu$	33%	1.6%
f_D	$D^+ \rightarrow \mu \nu$	~50%	2.3%

Br(D) & $\sigma(ee \rightarrow DD)$ @ $\sqrt{s} = \Psi(3770)$



$$B = \frac{2D}{S} \frac{\varepsilon_1}{\varepsilon_2}$$

i.e., L independent

If $\varepsilon_2 \approx \varepsilon_1^2$: $N_{DD} = \frac{S^2}{4D}$

$$\Rightarrow \sigma(D\bar{D}) = \frac{S^2}{4DL}$$

i.e., B & ε independent

Single and Double Tags

□ Determine 5 Br's and $\sigma(e^+e^- \rightarrow D^0\overline{D}^0)$ & $\sigma(e^+e^- \rightarrow D^+D^-)$

□ 10 Single Tag + 13 Double Tag modes

$$D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+ + \text{c.c.}$$

$$D^+ \rightarrow K^-\pi^+\pi^+, K_s\pi^+ + \text{c.c.}$$

□ Event selection similar to f_{D^+} analysis

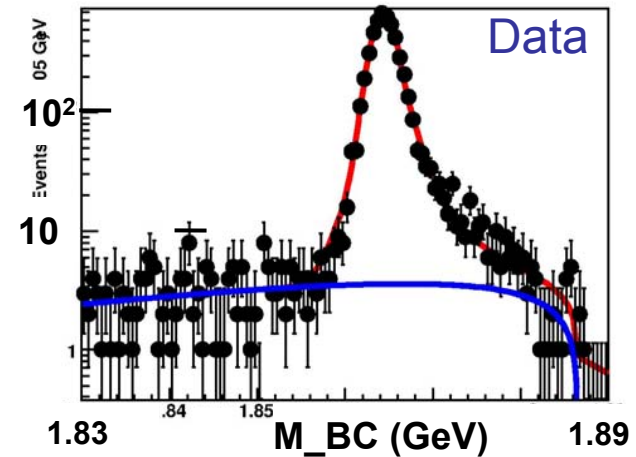
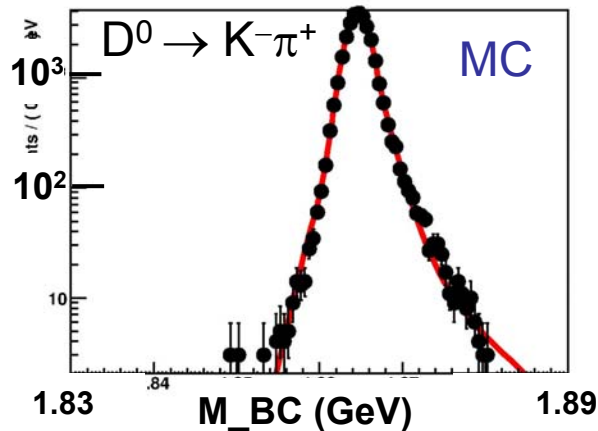
□ Key analysis variables:

$$\triangleright \Delta E = E_{\text{beam}} - \sum E_i$$

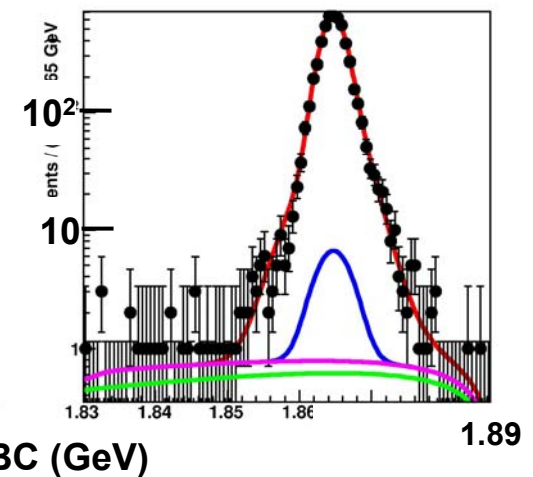
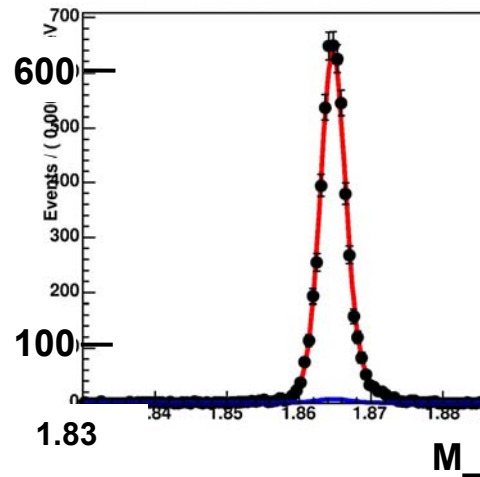
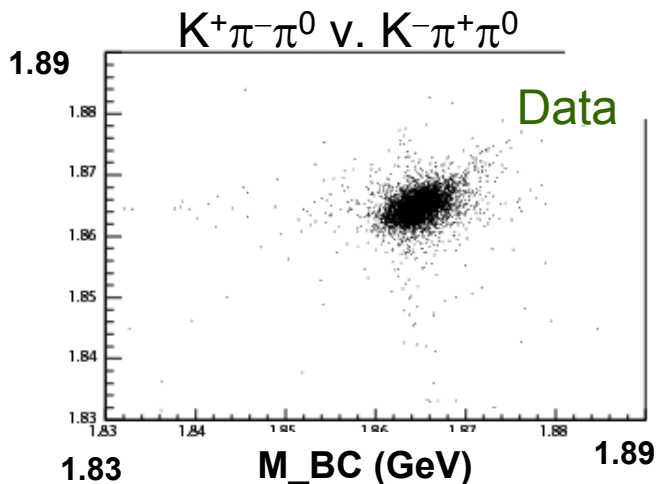
$$\triangleright M_{\text{BC}} = \sqrt{(E_{\text{beam}}^2 - (\sum \vec{p}_i)^2)}$$

Single and Double Tag Yields

- N(single tags) from ML fit to M_{BC}
- Line shape parameters from MC and data
- D and $\bar{D}$ fit together: same signal param's, indep. bkg.



- N(double tags) from 2-D ML fit to 2-D M_{BC}



Fit for Br(D) and $\sigma(D\bar{D})$

- χ^2 fit to account for correlations btwn single/double tags, bkg
- Fit Output: $\text{Br}(D^0 \rightarrow K^-\pi^+)$, $\text{Br}(D^0 \rightarrow K^-\pi^+\pi^0)$, $\text{Br}(D^0 \rightarrow K^-\pi^+\pi^-\pi^+)$
 $\text{Br}(D^+ \rightarrow K^-\pi^+\pi^+)$, $\text{Br}(D^+ \rightarrow K_s\pi^+)$ and $N(D^0\bar{D}^0)$, $N(D^+D^-)$
- Fit Input: S.T. & D.T. yields, ε_{tag} , ε_{bkg} + errors
- $\chi^2/\text{ndof} = 8.9/16$, C.L. = 92%

Fit Results for Br(D) and $\sigma(\text{DD})$

CLEO-c Preliminary

$$\begin{array}{ll} \text{Br}(D^0 \rightarrow K^- \pi^+) & (3.92 \pm 0.08 \pm 0.23) \% \\ \text{PDG} & (3.80 \pm 0.09) \% \end{array}$$

$$\begin{array}{ll} \text{Br}(D^0 \rightarrow K^- \pi^+ \pi^0) & (14.3 \pm 0.3 \pm 1.0) \% \\ \text{PDG} & (13.0 \pm 0.8) \% \end{array}$$

$$\begin{array}{ll} \text{Br}(D^0 \rightarrow K^- \pi^+ \pi^- \pi^+) & (8.1 \pm 0.2 \pm 0.9) \% \\ \text{PDG} & (7.46 \pm 0.31) \% \end{array}$$

$$\begin{array}{ll} \text{Br}(D^+ \rightarrow K^- \pi^+ \pi^+) & (9.8 \pm 0.4 \pm 0.8) \% \\ \text{PDG} & (9.2 \pm 0.6) \% \end{array}$$

$$\begin{array}{ll} \text{Br}(D^+ \rightarrow K_s \pi^+) & (1.61 \pm 0.08 \pm 0.15) \% \\ \text{PDG} & (1.41 \pm 0.10) \% \end{array}$$

$$N(D^0 \bar{D}^0) = 1.98 \times 10^5 \Rightarrow \sigma(D^0 \bar{D}^0) = 3.47 \pm 0.07 \pm 0.15 \text{ nb}$$

$$N(D^+ D^-) = 1.48 \times 10^5 \Rightarrow \sigma(D^+ D^-) = 2.59 \pm 0.11 \pm 0.11 \text{ nb}$$

$$\sigma(D \bar{D}) = 6.06 \pm 0.13 \pm 0.22 \text{ nb}$$

$$\sigma(e^+ e^- \rightarrow D^+ D^-) / \sigma(e^+ e^- \rightarrow D^0 \bar{D}^0) = 0.75 \pm 0.04 \pm 0.02$$

CLEO-c Physics Reach for Br(D)

- Large data sets planned for $\sqrt{s} = \Psi(3770)$ and $\sqrt{s} \sim 4140$ MeV

w/ 3 fb^{-1}

Mode	$\sqrt{s}$ (GeV)	PDG04 ($\delta B/B$ %)	CLEO-c ($\delta B/B$ %)
$D^0 \rightarrow K^- \pi^+$	3770	2.4	0.6
$D^+ \rightarrow K^- \pi^+ \pi^+$	3770	6.5	0.7
$D_s \rightarrow \phi \pi$	4140	25	1.9

CLEO-c Outlook

Yr 1: $\psi(3770) - 3 \text{ fb}^{-1}$

18M DD events, w/ 3.6M *tagged* D decays
(150 times MARK III)

Yr 2: $\sqrt{s} \sim 4100 \text{ MeV} - 3 \text{ fb}^{-1}$

1.5M $D_s D_s$ events, w/ 0.3M *tagged* D_s decays
(480 times MARK III, 130 times BES)

Yr 3: $\psi(3100) - 1 \text{ fb}^{-1}$

1×10^9 J/ ψ decays
(170 times MARK III, 15 times BES II)

- CLEO-c: precision charm absolute Br measurements

Leptonic decays $\rightarrow$ decay constants

Semileptonic decays $\rightarrow V_{cd}, V_{cs}, V_{CKM}$ unitarity check, form factors

Absolute D Br's normalize B physics

Test QCD techniques in c sector, apply to b sector

$\Rightarrow$ improved $V_{ub}, V_{cb}, V_{td}, V_{ts}$

Physics beyond SM: where is it?

- CLEO-c: D-mixing, charm CPV, charm/tau rare decays.