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

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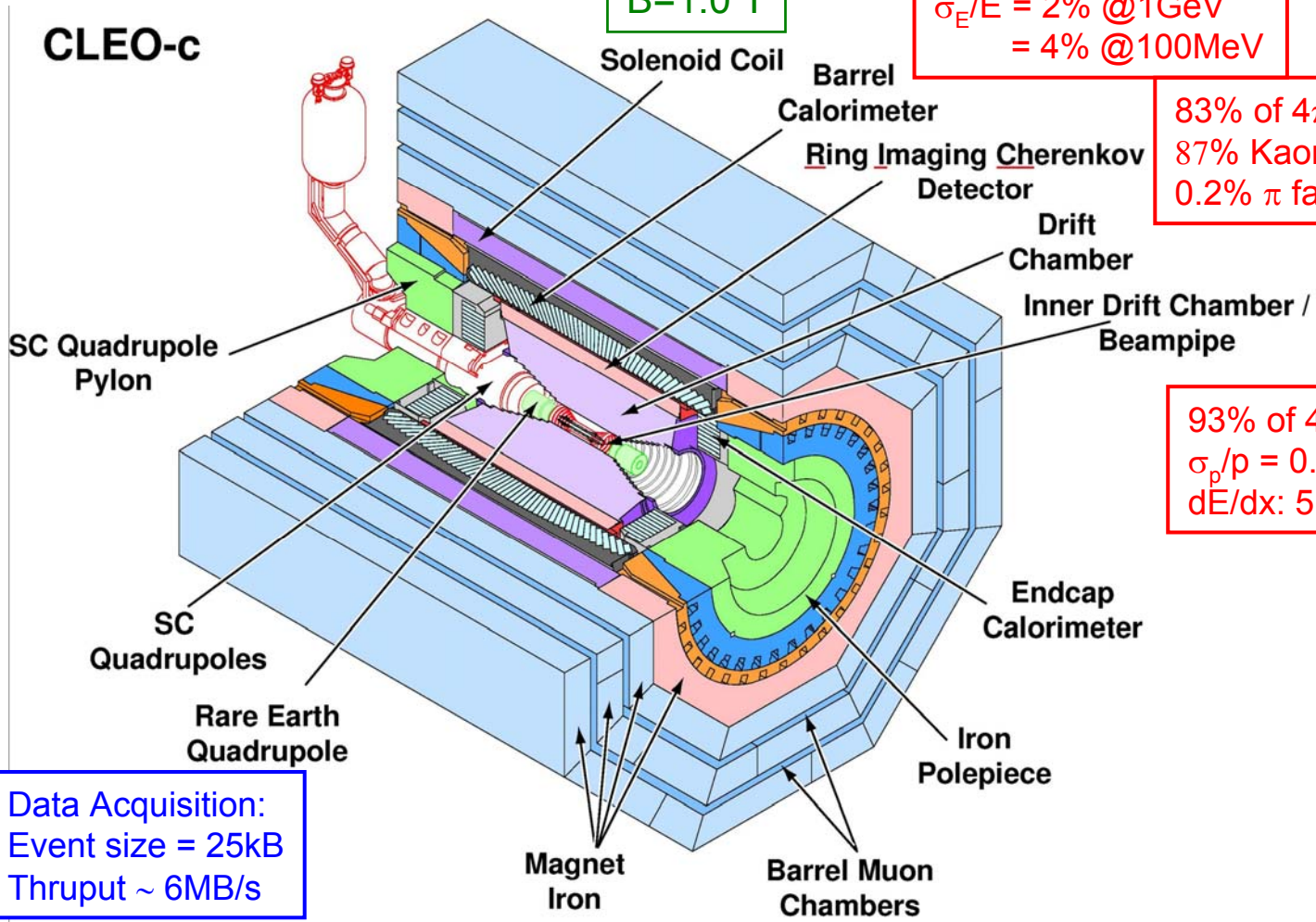
CLEO Collaboration

- $D^+ \to \mu^+ \nu_\mu$ Decays
- Absolute *Br*(D $\to$ hadrons)
- σ ($e^+e^- \to D\overline{D}$)
- CLEO-c Outlook

CLEO-c Detector



93% of 4π
σ_E/E = 2% @1GeV
= 4% @100MeV

83% of 4π
87% Kaon ID with
0.2% π fake @0.9GeV

93% of 4π
σ_p/p = 0.3% @1GeV
dE/dx: 5.7% π @minI

Data Acquisition:
Event size = 25kB
Thruput ~ 6MB/s

Trigger : Tracks & Showers Pipelined
Latency = 2.5 μs

85% of 4π
p>1 GeV

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

$$Br(D_q \to l\nu) = \frac{G_F^2}{8\pi} m\_D_q m_l^2 \left(1 - \frac{m_l^2}{m^2\_D_q}\right) f^2\_D_q |V_{cq}|^2 \tau\_D_q$$

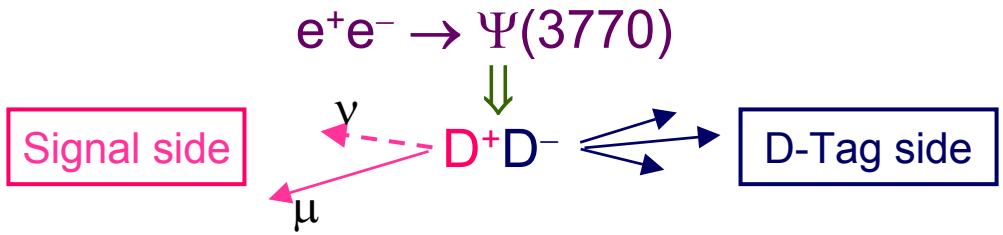
Weak Physics

Strong 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-mixing m'ments $\Rightarrow |V_{td}/V_{ts}|$ precision

Single $D^{\pm}$ Tag



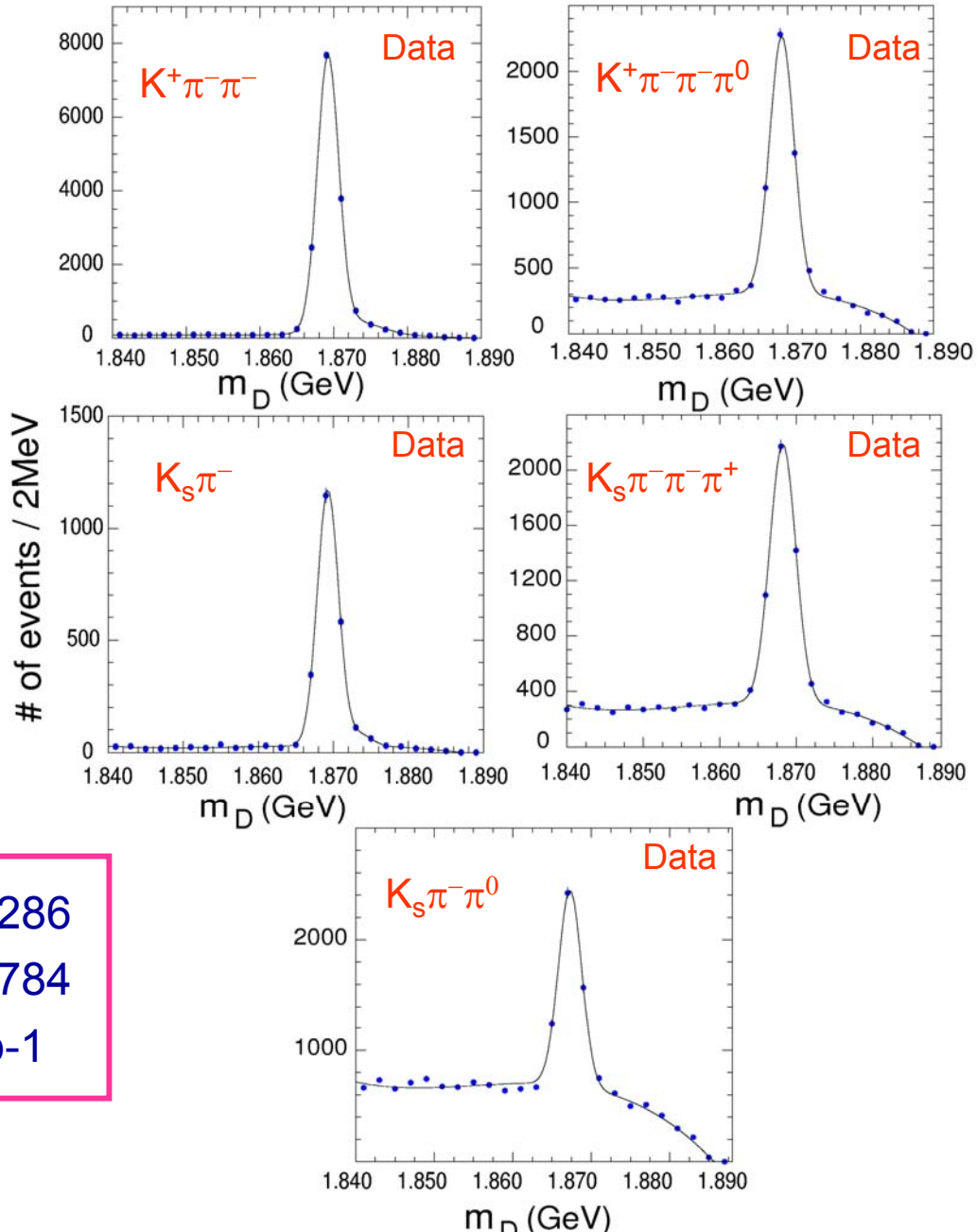
$D^+ \rightarrow \mu^+\nu$
- 1 track from event vertex, min_I in CsI
- "small" (< 250 MeV) neutral E loss in CsI
- no reconstructed K_s

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

❖ Key analysis variables:
- ➢ $M_D^2 = E_{beam}^2 - (\Sigma \vec{p}_i)^2$
- ➢ $MM^2 = (E_{beam} - E_\mu)^2 - (-\vec{p}_D - \vec{p}_\mu)^2$ (Sensitive to ν's in FS)

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

M_D Distribution v. D Tag



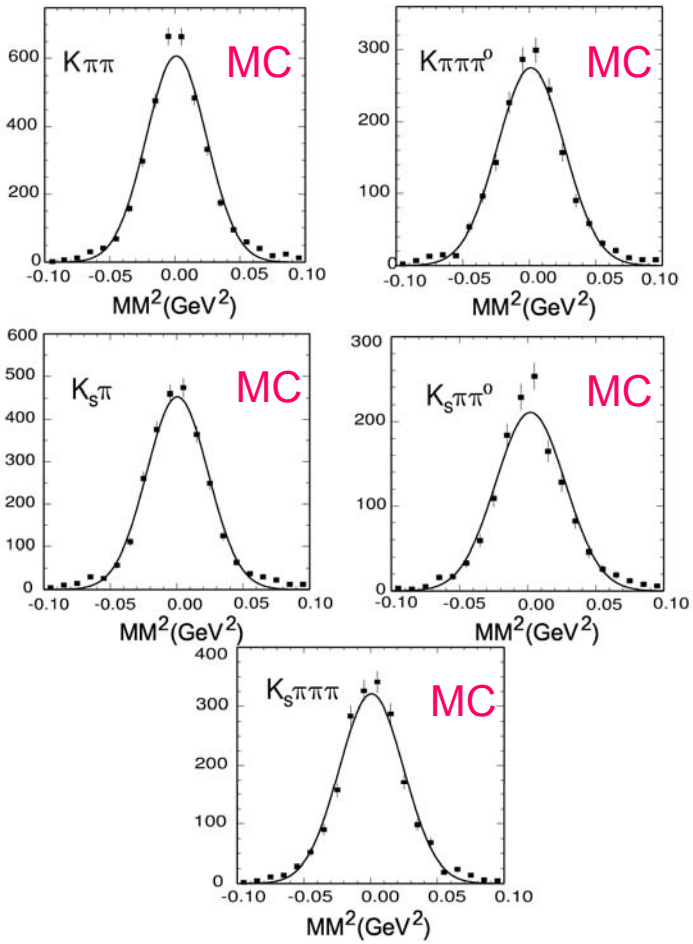
S: 28575 ± 286

B: 8765 ± 784

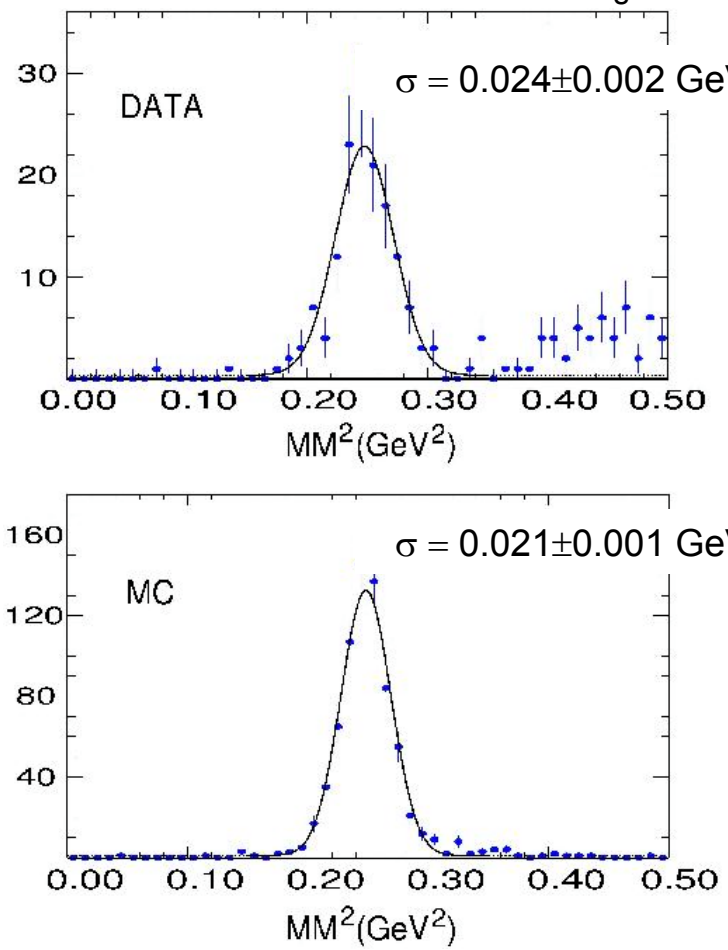
∫Ldt = 57 pb-1

MM^2 Distribution v. D Tag

- Set search window in signal side MM2 distribution



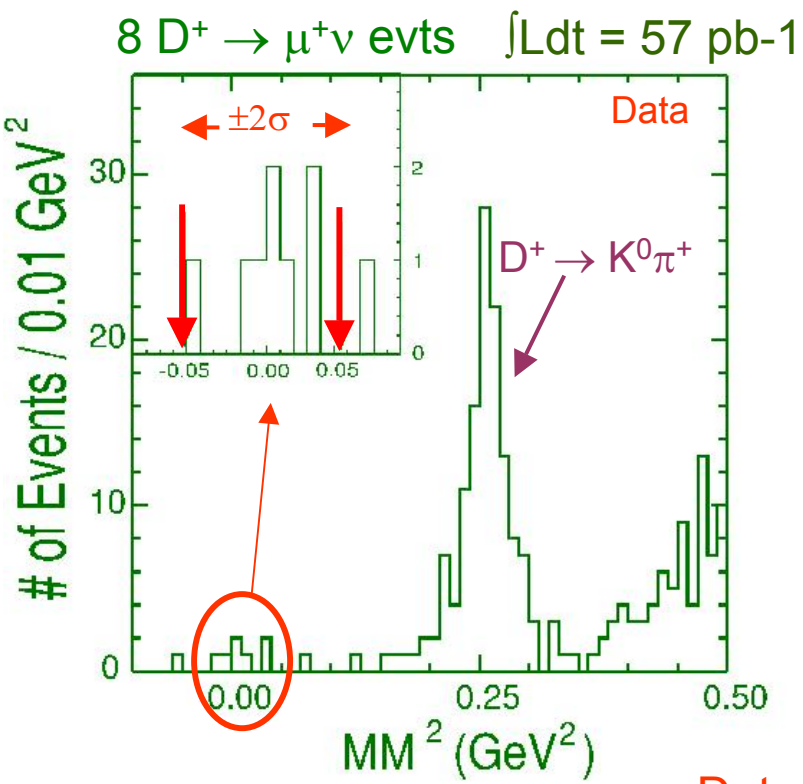
$D^- \rightarrow K_s\pi^-$

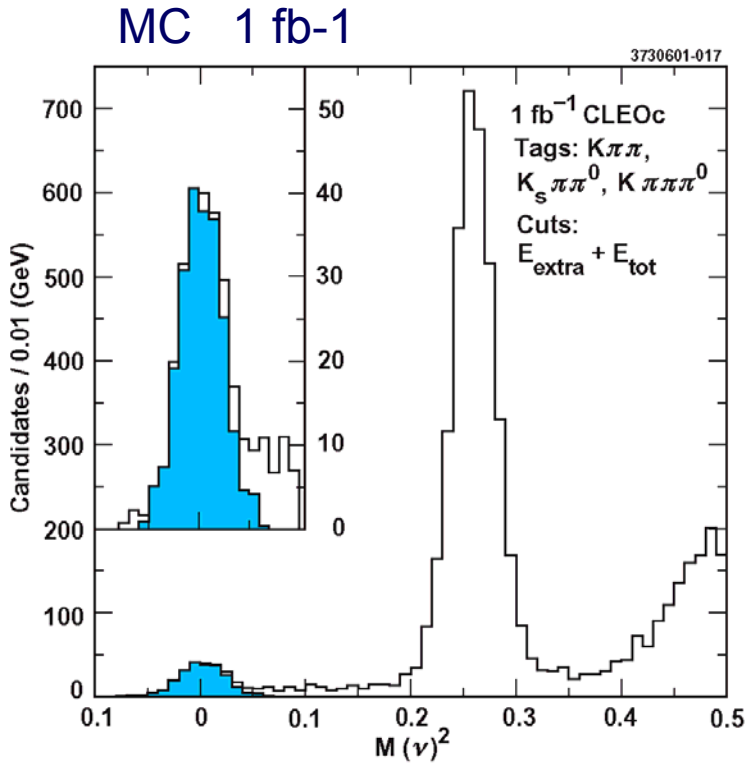


$\sigma(MM^2) \approx 0.025\ GeV^2$

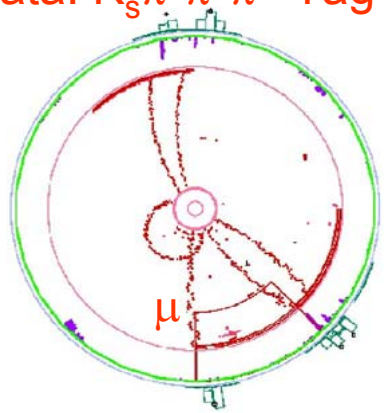
$\sigma = (0.024/0.021)*0.025 = 0.028\ GeV^2$

Leptonic Decays: Signal Region





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



Background + Results

Background estimates via MC

- $D^{\pm}$ Background:

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

- $D^0\overline{D}^0$ Background: 0.16 ± 0.16 events
- $e^+e^- \to$ continuum: 0.17 ± 0.17 events

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

$$Br(D^+ \to \mu^+\nu) = \frac{N_{sig}}{\varepsilon * N_{tag}}$$ & ε = 69.9% for $D^+ \to \mu^+\nu$ recon.

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

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

CLEO-c Preliminary

$\int Ldt = 57$ pb-1

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

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

BES: hep-ex/0406027

$\int Ldt = 17.7$ pb-1

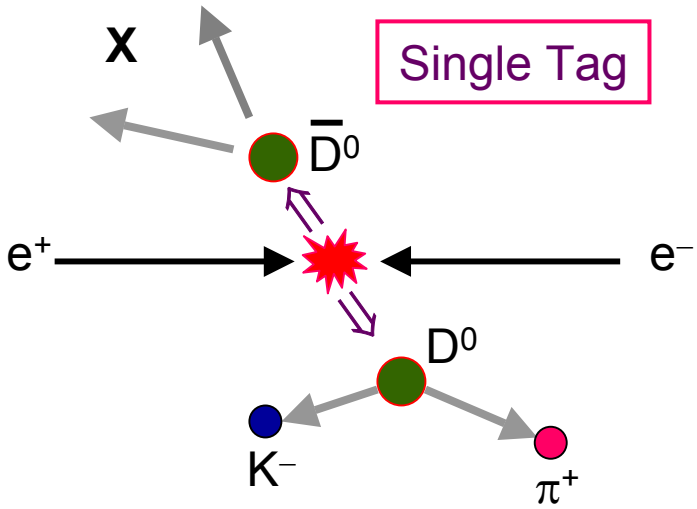
CLEO-c Physics Reach for f_D

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

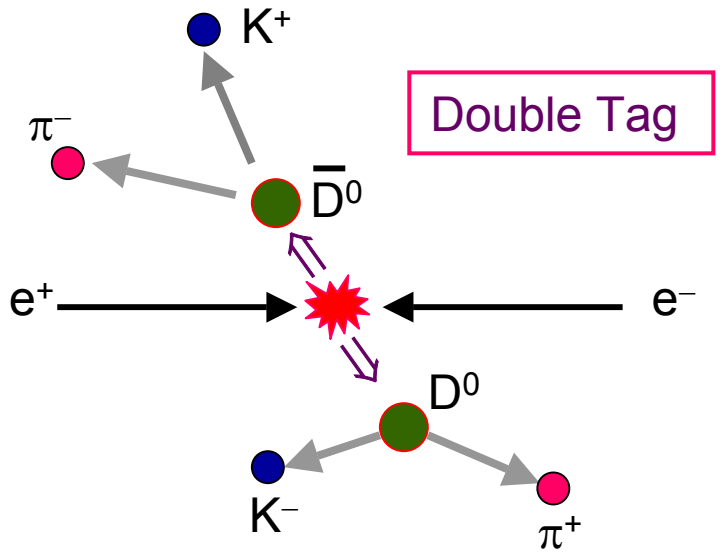
w/ 3 fb-1 & 3-gen CKM unitarity:

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

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



$S = 2N_{DD}\, B\varepsilon_1$



$D = N_{DD}\, B^2\varepsilon_2$

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

i.e., *L* independent

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

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

i.e., B & ε independent

Single and Double Tags

- Determine 5 Br's and $\sigma(e^+e^- \to D^0\overline{D^0})$ & $\sigma(e^+e^- \to D^+D^-)$
- 10 Single Tag + 13 Double Tag modes

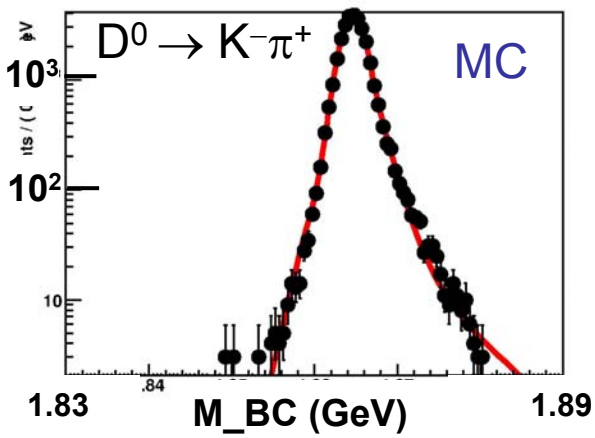
  $D^0 \to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+$ + c.c.

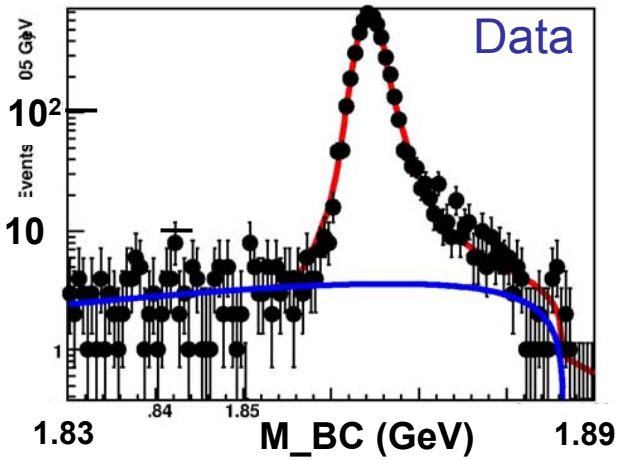
  $D^+ \to K^-\pi^+\pi^+, K_s\pi^+$ + c.c.

- Event selection similar to f_{D+} analysis
- Key analysis variables:
  - $\Delta E = E_{beam} - \Sigma E_i$
  - $M_{BC} = \sqrt{(E_{beam}^2 - (\vec{\Sigma} p_i)^2)}$

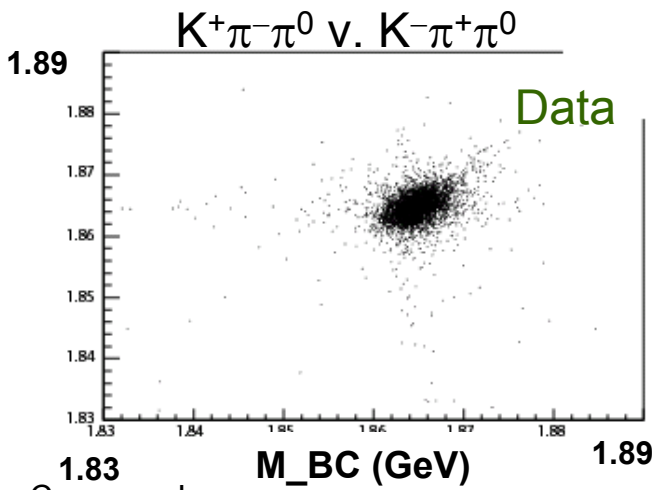
Single and Double Tag Yields

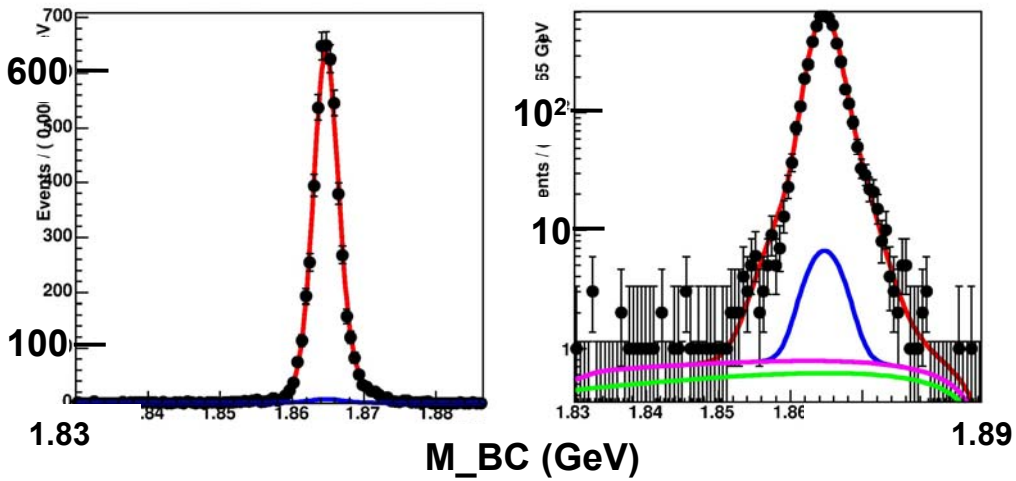
- N(single tags) from ML fit to M_BC
- Line shape parameters from MC and data
- D and $\overline{D}$ fit together: same signal param's, indep. bkg.





- 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: $Br(D^0 \to K^-\pi^+)$, $Br(D^0 \to K^-\pi^+\pi^0)$, $Br(D^0 \to K^-\pi^+\pi^-\pi^+)$
  $Br(D^+ \to K^-\pi^+\pi^+)$, $Br(D^+ \to K_s\pi^+)$ and $N(D^0\bar{D}^0)$, $N(D^+D^-)$
- Fit Input: S.T. & D.T. yields, ε_tag, ε_bkg + errors
- χ^2/ndof = 8.9/16, C.L. = 92%

Fit Results for Br(D) and σ(DD)

CLEO-c Preliminary

$Br(D^0 \to K^-\pi^+)$	$(3.92 \pm 0.08 \pm 0.23)$ %
PDG	(3.80 ± 0.09) %
$Br(D^0 \to K^-\pi^+\pi^0)$	$(14.3 \pm 0.3 \pm 1.0)$ %
PDG	(13.0 ± 0.8) %
$Br(D^0 \to K^-\pi^+\pi^-\pi^+)$	$(8.1 \pm 0.2 \pm 0.9)$ %
PDG	(7.46 ± 0.31) %
$Br(D^+ \to K^-\pi^+\pi^+)$	$(9.8 \pm 0.4 \pm 0.8)$ %
PDG	(9.2 ± 0.6) %
$Br(D^+ \to K_s\,\pi^+)$	$(1.61 \pm 0.08 \pm 0.15)$ %
PDG	(1.41 ± 0.10) %

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

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

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

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

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 ($\delta B/B$ %)
$D^0 \to K^-\pi^+$	3770	2.4	0.6
$D^+ \to K^-\pi^+\pi^+$	3770	6.5	0.7
$D_s \to \phi\pi$	4140	25	1.9

CLEO-c Outlook

Yr 1: $\psi(3770)$ – 3 fb^{-1}
18M DD events, w/ 3.6M *tagged* D decays
(150 times MARK III)

Yr 2: $\sqrt{s} \sim 4100$ MeV – 3 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 fb^{-1}
1 x10^9 J/ψ decays
(170 times MARK III, 15 times BES II)

• CLEO-c: precision charm absolute Br measurements

Leptonic decays → decay constants

Semileptonic decays →Vcd, Vcs, V_CKM unitarity check, form factors

Absolute D Br's normalize B physics

Test QCD techniques in c sector, apply to b sector

⇒ improved Vub, Vcb, Vtd, Vts

Physics beyond SM: where is it?

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