Experimental Outlook for Charm Physics

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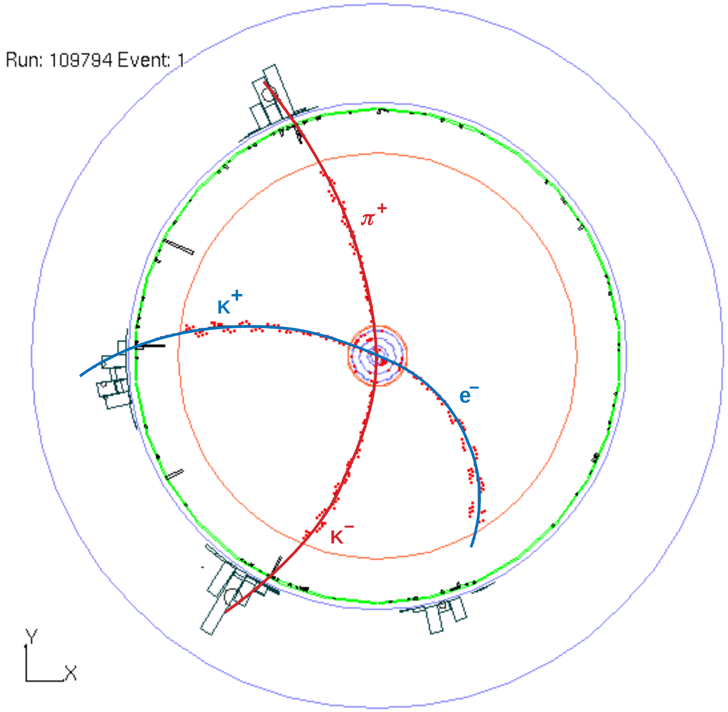
CLEO Collaboration

- Why charm threshold
- Accessible Physics
- Some details
- Detectors
- Summary

Why Charm Threshold?

- Large production σ, low decay multiplicity
- Pure initial state ($D\bar{D}$): no fragmentation
- Double tag events: no background
- Clean neutrino reconstruction
- Quantum coherence:

  aids D-$\bar{D}$ mixing and CPV studies



$D^0 \rightarrow K^- \pi^+$ $\bar{D}^0 \rightarrow K^+ e^- \nu$

Motivation

- $D \to l\nu$: f_D & f_{Ds}
- $D \to P\, l\, \nu$: V_{cd} & $V_{cs;}$ also $f(q^2)$
- Improve $\delta V_{ub}/V_{ub}$ & $\delta V_{cb}/V_{cb}$
- Improve $\delta V_{td}/V_{td}$ & $\delta V_{ts}/V_{ts}$ via B mixing
- Unitarity checks of V_CKM
- Definitive glueball searches
- CPV, $D\text{-}\bar{D}$ mixing, rare decays

CLEO-c Run Plan

Started Nov 2001

2002: Υ(1S), Υ(2S), Υ(3S),… ~1-2 fb^{-1} each
Spectroscopy, matrix element, Γ_{ee}
10-20 X existing world's data set

CLEO-c

2003: ψ(3770) – 3 fb^{-1}
30M DD events, w/ 6M *tagged* D decays
(310 times MARK III)

2004: √s ~ 4100 MeV – 3 fb^{-1}
1.5M D_sD_s events, w/ 0.3M *tagged* D_s decays
(480 times MARK III, 130 times BES)

2005: ψ(3100) – 1 fb^{-1}
1 Billion J/ψ decays
(170 times MARK III, 15 times BES II)

CESR-c Accelerator

- Modify for low energy operation:

  w/o extra radiation damping, $L \sim E^4$ ($L \sim 1.3 \times 10^{33}$ @ Υ(4S))

  w/ wigglers (transverse cooling), $L \sim E^2$ (cost $5M)

Expected machine performance:

$\sqrt{s}$	L (10^{32} cm^{-2} s^{-1})
3.77 GeV	3.0
4.1 GeV	3.6
3.1 GeV	2.0

- $\Delta E_{beam} \sim 1.2$ MeV at J/ψ

Tagging Technology

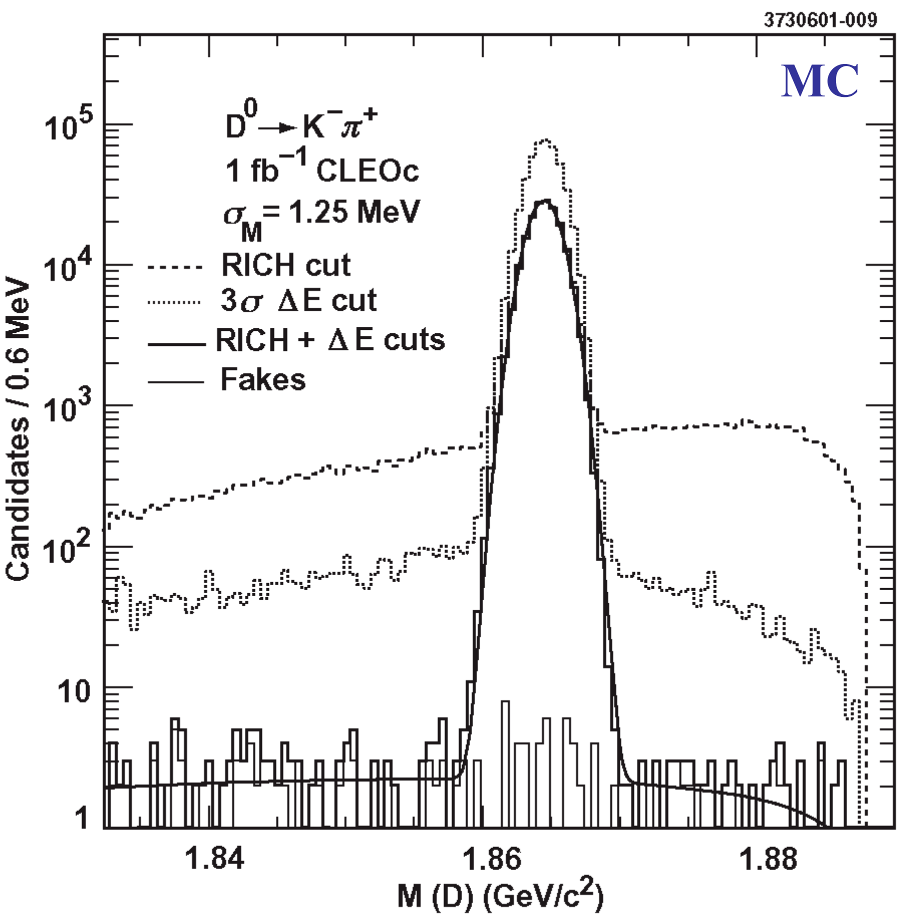
Pure DD/D_sD_s production: $\psi(3770) \rightarrow DD$

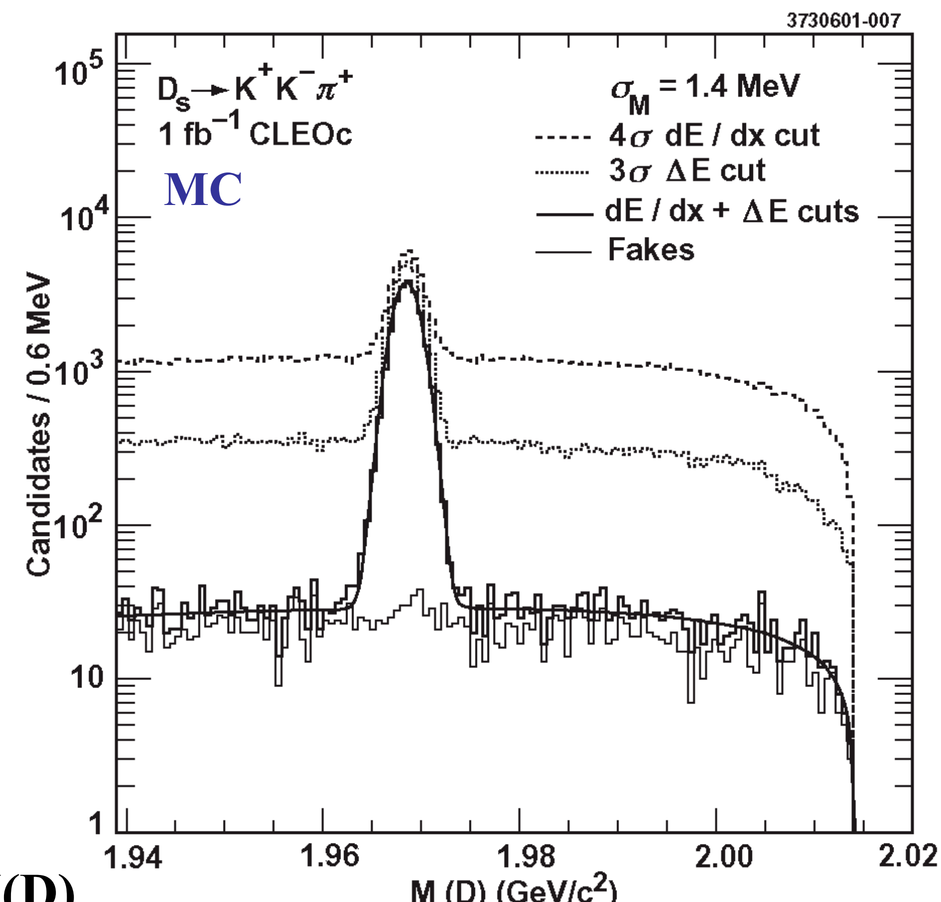
$\sqrt{s} \sim 4140 \rightarrow D_sD_s$

Large branching fractions (~1-15%)

High reconstruction efficiency

$\Rightarrow$ High net tagging efficiency ~20%



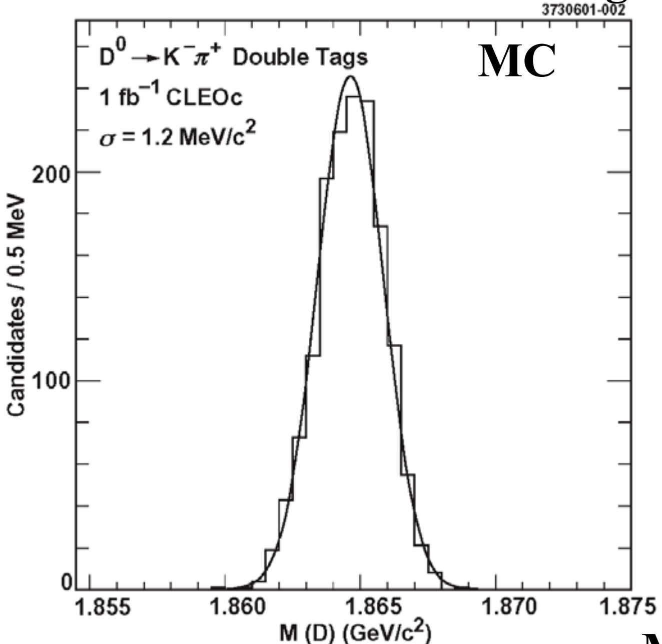


M(D)

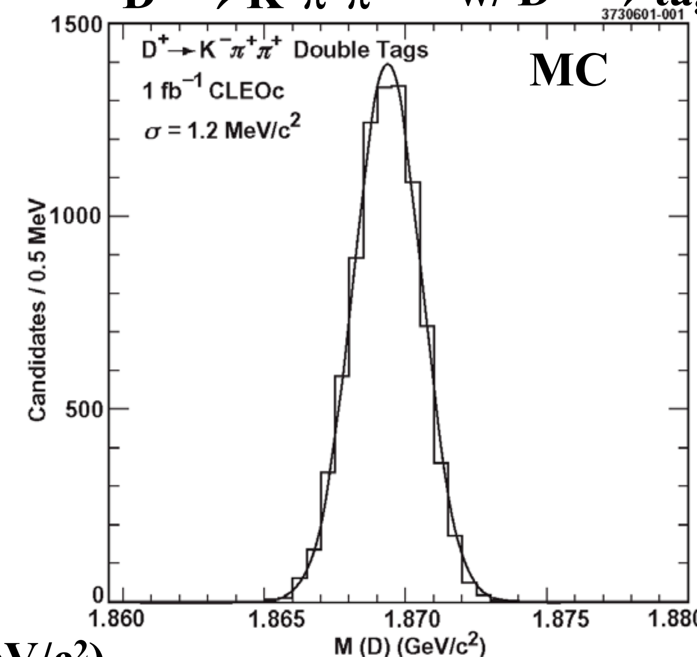
Absolute Br's w/ Double Tags

~ Zero bkgnd in hadronic modes

$D^0 \to K^-\pi^+$ w/ $\bar{D}^0 \to$ tag



$D^+ \to K^-\pi^+\pi^+$ w/ D^- $\to$ tag



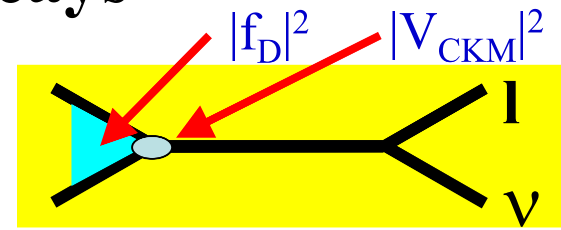
M(D) (GeV/c^2)

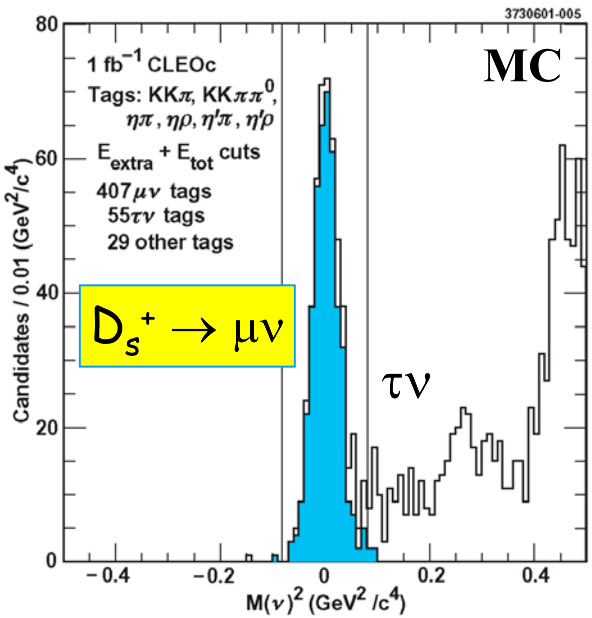
w/ 3 fb^{-1}

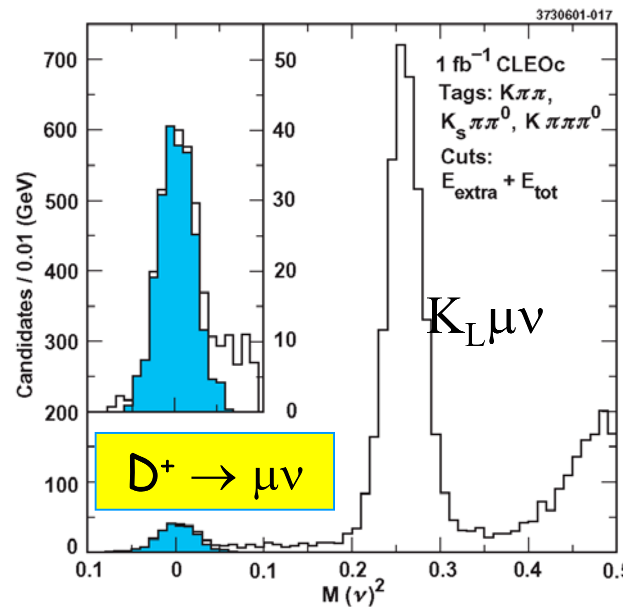
Mode	$\sqrt{s}$ (GeV)	PDG02 ($\delta B/B$ %)	CLEOc ($\delta B/B$ %)
$D^0 \to K^-\pi^+$	3770	2.4	0.6
$D^+ \to K^-\pi^+\pi^+$	3770	7.2	0.7
$D_s \to \phi\pi$	4140	25	1.9

f_{Dq} from Leptonic Decays

$$\Gamma\,(D_q \rightarrow l\,\nu) \propto |f\_Dq|^2\ |V\_cq|^2$$



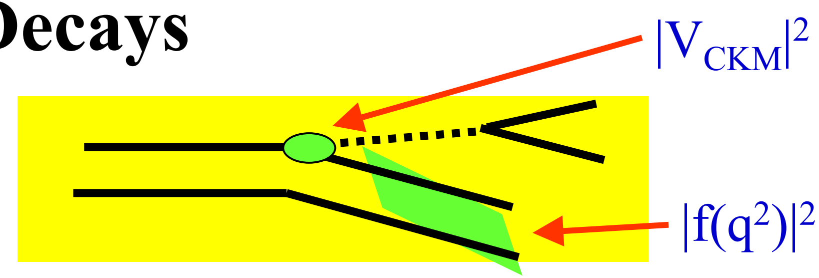




w/ 3 fb-1 & 3-gen CKM unitarity:

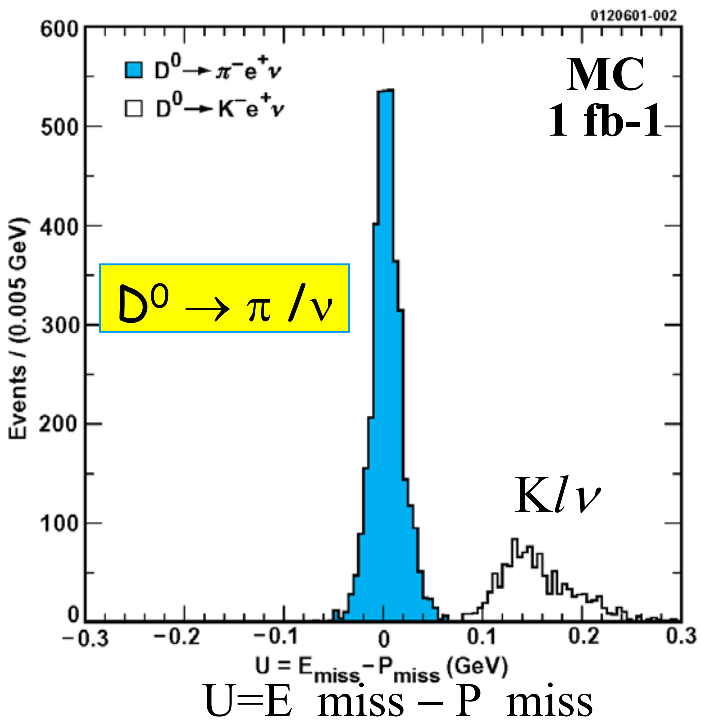
Decay Constant	Reaction	PDG $\delta f/f$	CLEO-c $\delta f/f$
f_{Ds}	$D_s^+ \rightarrow \mu\nu$	17%	1.9%
f_{Ds}	$D_s^+ \rightarrow \tau\nu$	33%	1.6%
f_D	$D^+ \rightarrow \mu\nu$	UL	2.3%

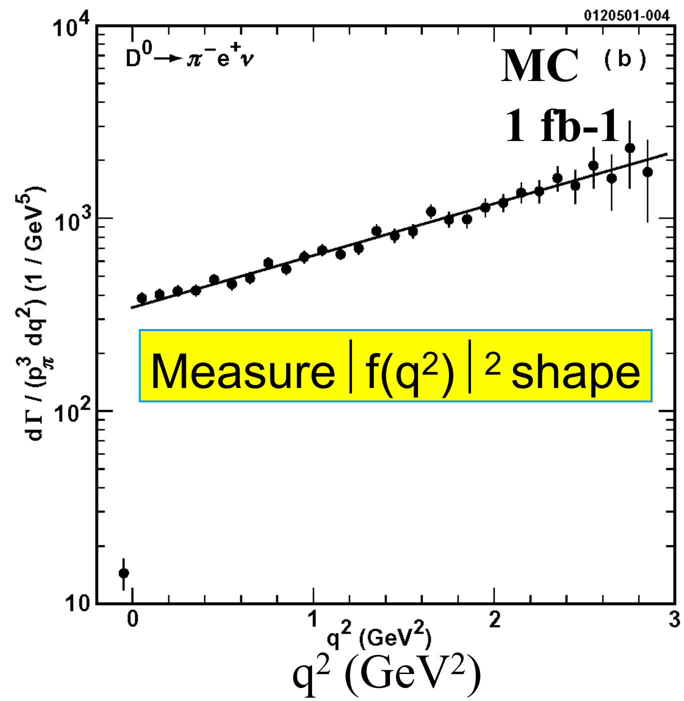
Semileptonic Decays



$$Br\,(D \to P\,l\,\nu)\,/\,\tau_D \;=\; \Gamma = \gamma\,|V\_cq|^2$$

$$d\Gamma\,(D \to P\,l\,\nu)\,/\,dq^2 \;\propto\; |V\_cq|^2\,|f_+(q^2)|^2$$





Mode	PDG02 ($\delta B/B\%$)	CLEOc ($\delta B/B\%$)
$D^0 \to K\, l\, \nu$	5	0.4
$D^0 \to \pi\, l\, \nu$	16	1.0
$D^+ \to \pi\, l\, \nu$	48	2.0
$Ds \to \phi\, l\, \nu$	25	3.1

$\therefore\ \delta V_{cd}/V_{cd}\ \&\ \delta V_{cs}/V_{cs} \sim 1.6\%$

$\delta V_{cd}/V_{cd} = 7\%$ (PDG02)

$\delta V_{cs}/V_{cs} = 11\%$ (PDG02)

Compare to B Factories

	CLEO-c 2 - 4 fb-1	BaBar 400 fb-1	Current Knowledge
f_D	2.3%	10 - 20%	NA
f_Ds	1.7%	6 - 9%	19%
Br (D+ -> Kππ)	0.7%	3 - 5%	7%
Br (Ds -> φπ)	1.9%	5- 10%	25%
Br (D0 -> Kπ)	0.6%	2 - 3%	2%

Statistics limited

Systematics and bkgnd limited

V_{cd} & V_{cs}

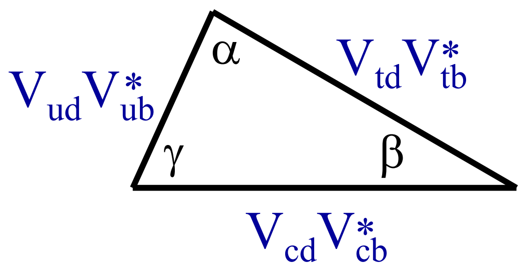
CPV in SM: V_CKM

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

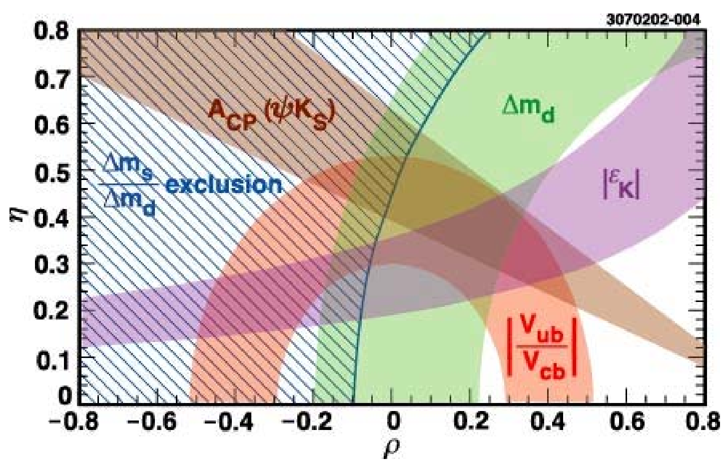
3 angles + 1 phase (CP violating)

<u>Hierarchy</u>: $\sim 1, \sim\lambda, \sim\lambda^2, \sim\lambda^3$

($\lambda \approx 0.22$)



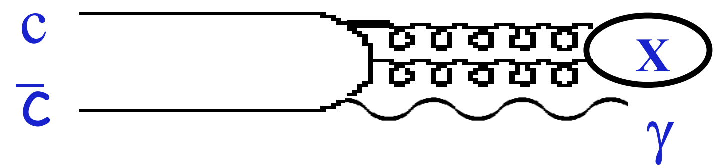
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



Expt'l Goal: Overconstrain V_CKM

Probing QCD

- Gluons carry color charge ⇒ binding: Glueballs = | gg > and Hybrids = | qqg >

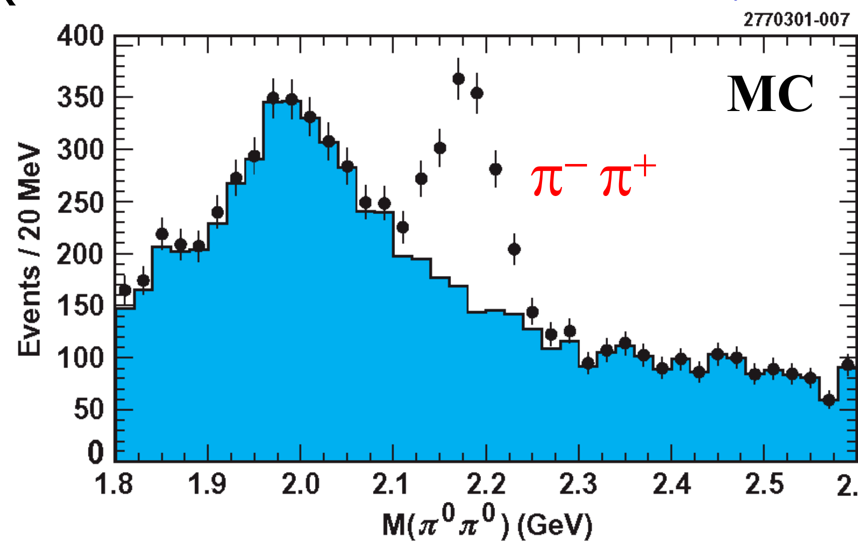


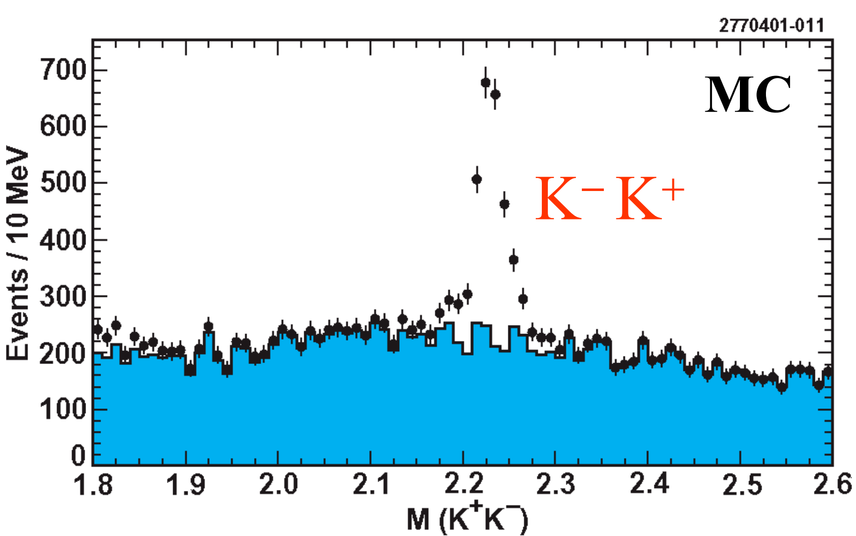
- Radiative Ψ decays: ideal glue factory
- CLEO-c: ~10^9 J/Ψ decays ⇒ ~ 60M J/Ψ → γX

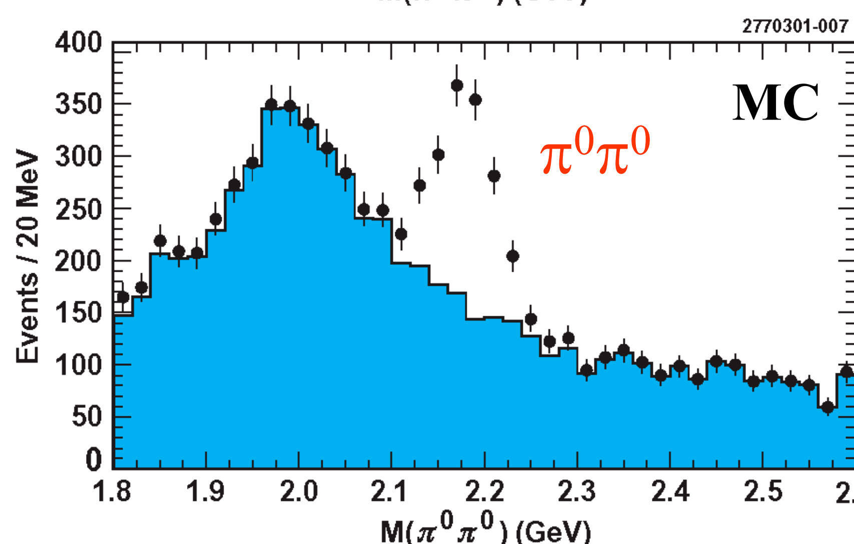
  Partial Wave Analysis

  Absolute Br's: ππ, KK, pp, ηη, ...
- E.g.: $f_J(2220)$

∴CLEO-c: find/debunk $f_J(2220)$

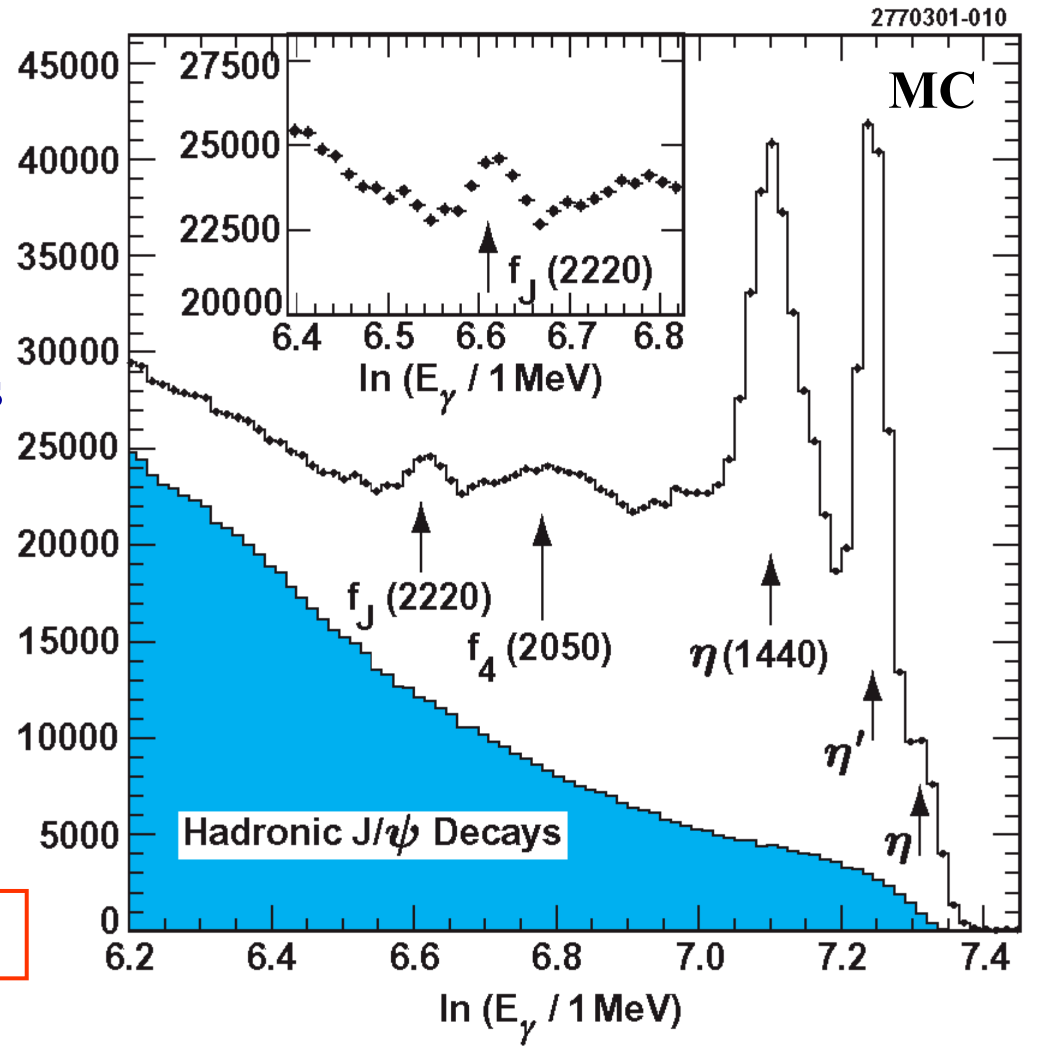






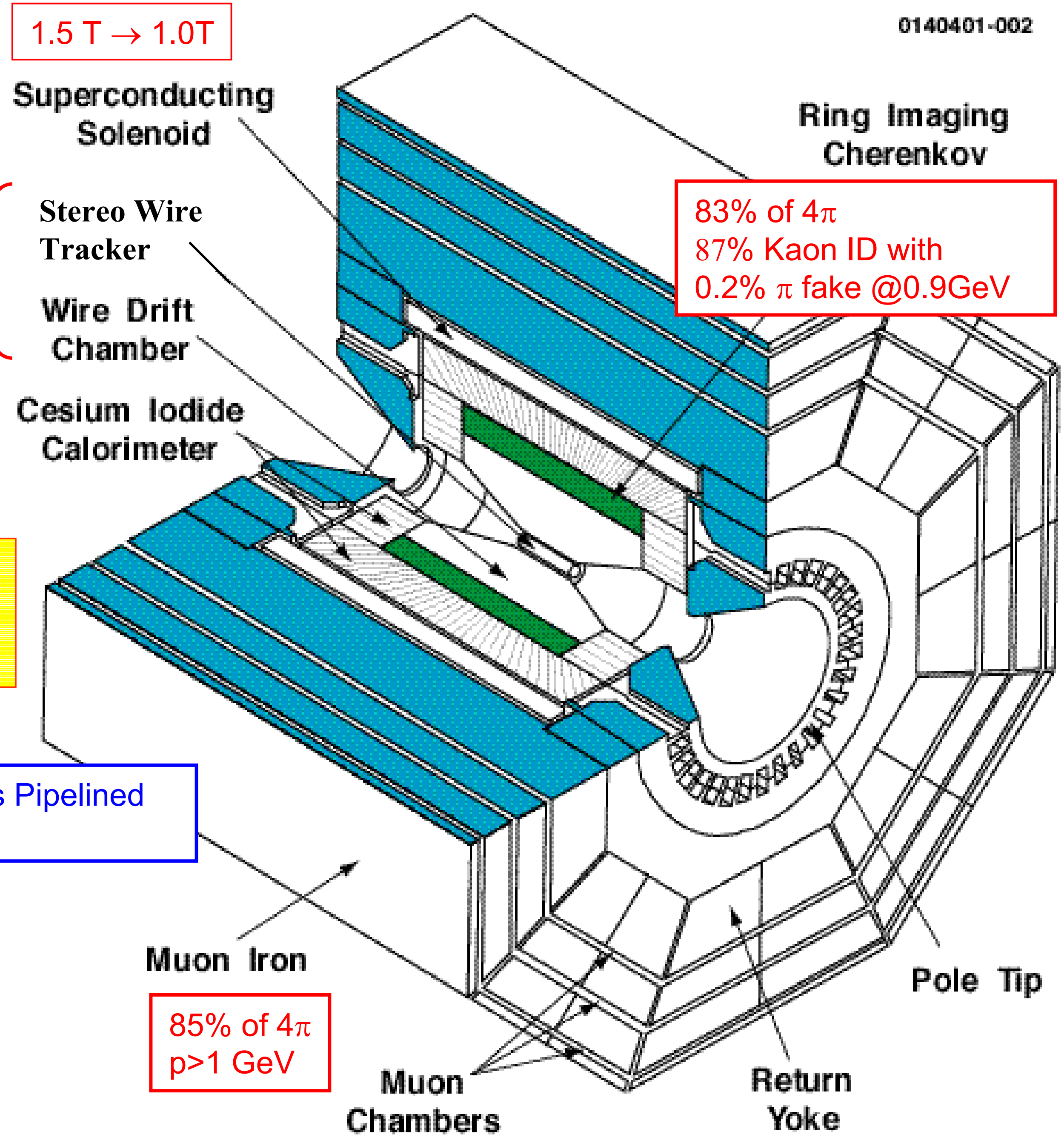
$J/\Psi \rightarrow \gamma X$ Inclusive γ - Spectrum

- Inclusive γ -spectrum
  Search for monochromatic γ
  E.g., 24% efficient for $f_J(2220)$
  $\sim 10^{-4}$ sensitivity for narrow resonances
- Modern 4π detector
  Suppress hadronic bkgnd: $J/\psi \rightarrow \pi^0 X$
- Huge data set
  Plus $\gamma\gamma$ and Y(1S) data



Determine J^{PC} and gluonic content

CLEO III Detector → CLEO-c Detector



$1.5\ T \rightarrow 1.0T$

93% of 4π
$\sigma_p/p = 0.35\%$ @1GeV
dE/dx: 5.7% π @minI

93% of 4π
$\sigma_E/E = 2\%$ @1GeV
$= 4\%$ @100MeV

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

85% of 4π
p>1 GeV

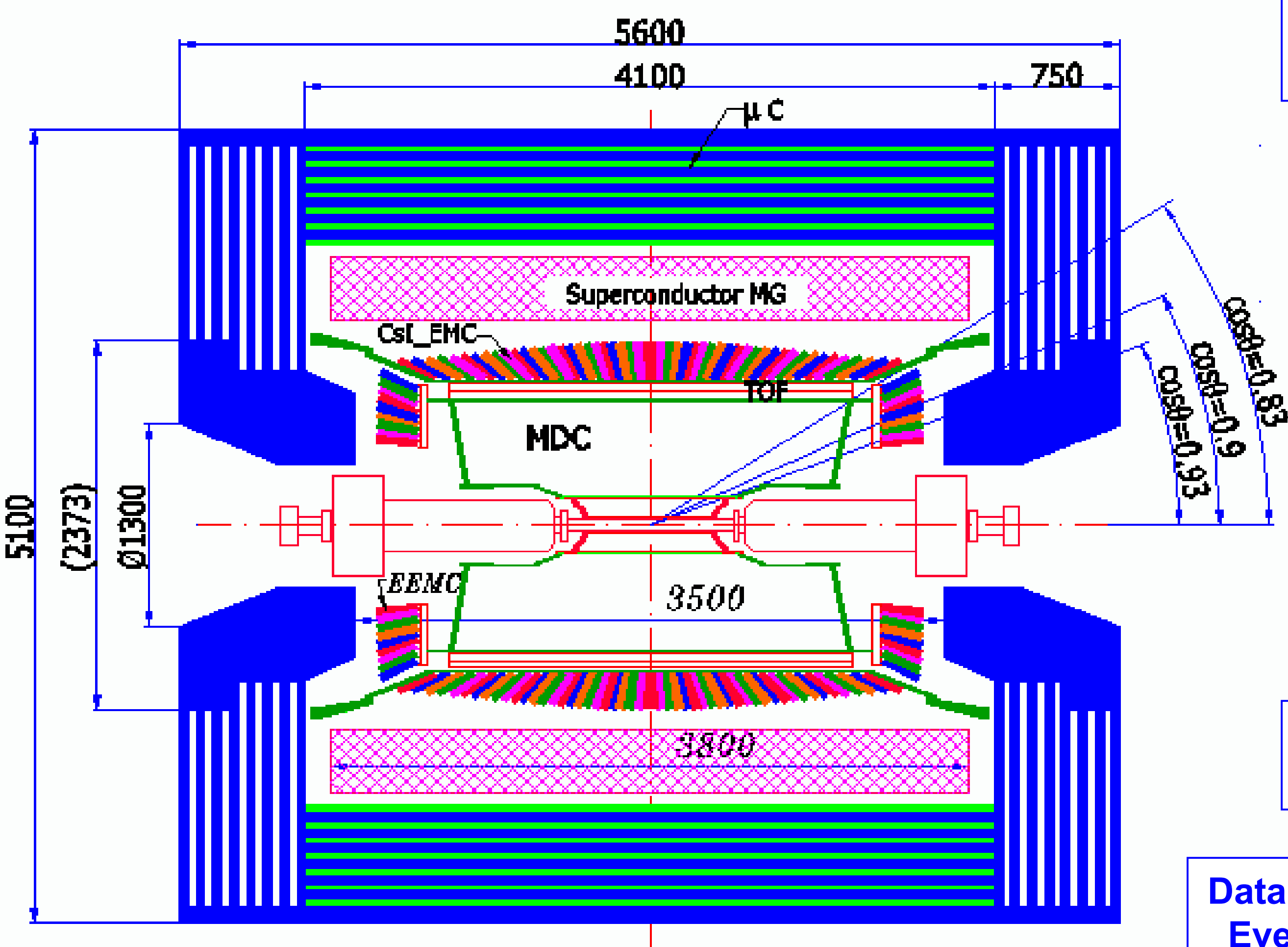
Trigger : Tracks & Showers Pipelined
Latency = 2.5 μs

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

BESIII

Magnet:
- 0.4-0.5 T existing BESII magnet
- 1 T Super conducting magnet

MDC: small cell & He gas
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%



TOF:
σ_T = 80 ps Barrel
100 ps Endcap

EMCAL: CsI crystal
σ_E/E = 2.5% @1GeV
σ_z = 0.5 cm/$\sqrt{E}$

Muon ID: 9 layer RPC

Trigger: Tracks & Showers
Pipelined; Latency = 2.4μs

Data Acquisition:
Event rate = 3KHz
Thruput ~ 50 MB/s

Thanks H.S. Chen

Summary

- $D\bar{D}$ threshold running:
  - key kinematic advantages
  - huge physics reach: f_D, f_{Ds}, $f_+(q^2)$, V_CKM, …
- Physics: Fall ’03 (CLEO-c) &2006 (BESIII)