Rensselaer

CORNELL UNIVERSITY LEPP
LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

Charm and QCD at CLEO-III and CLEO-c

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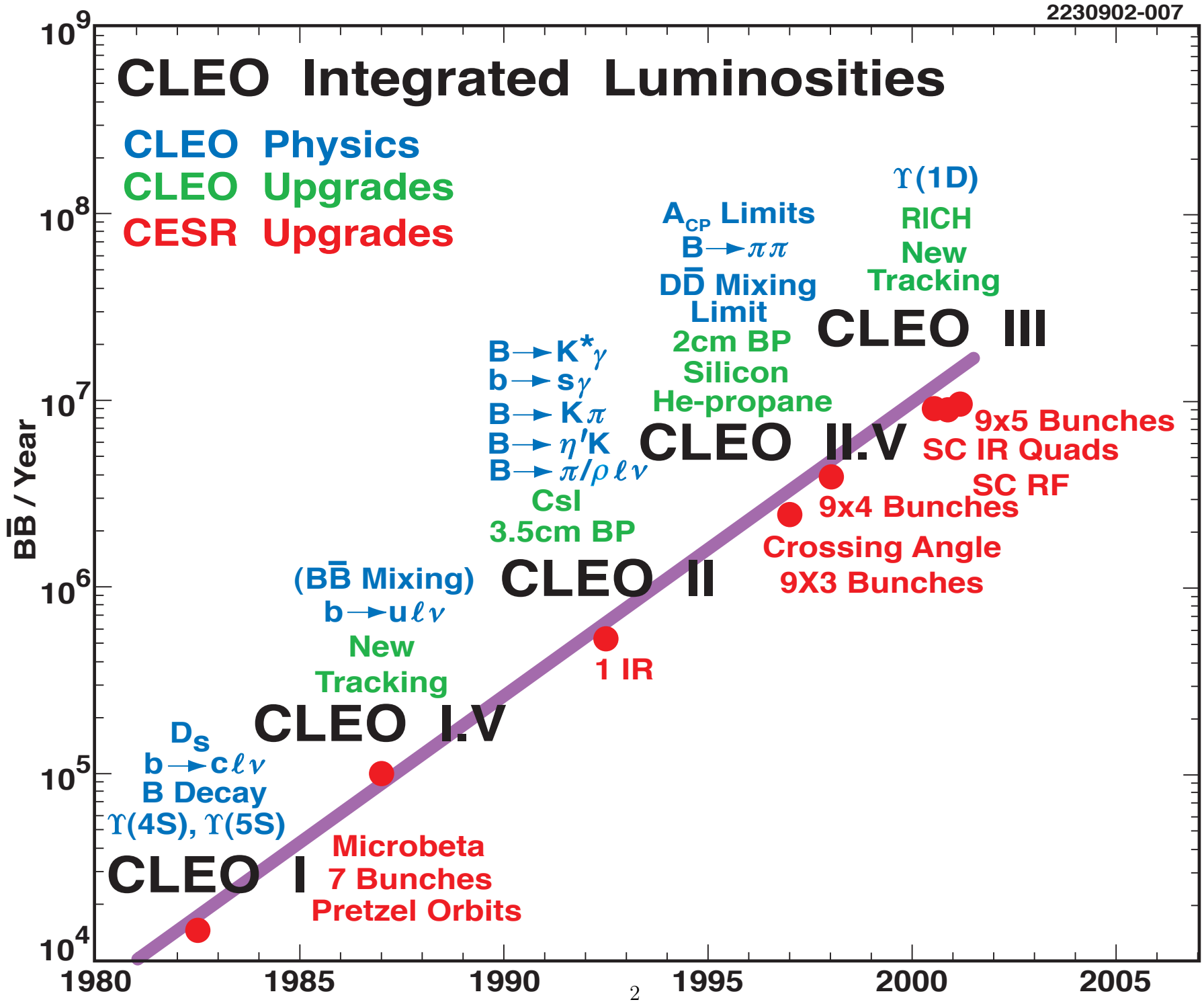
Physics topics:

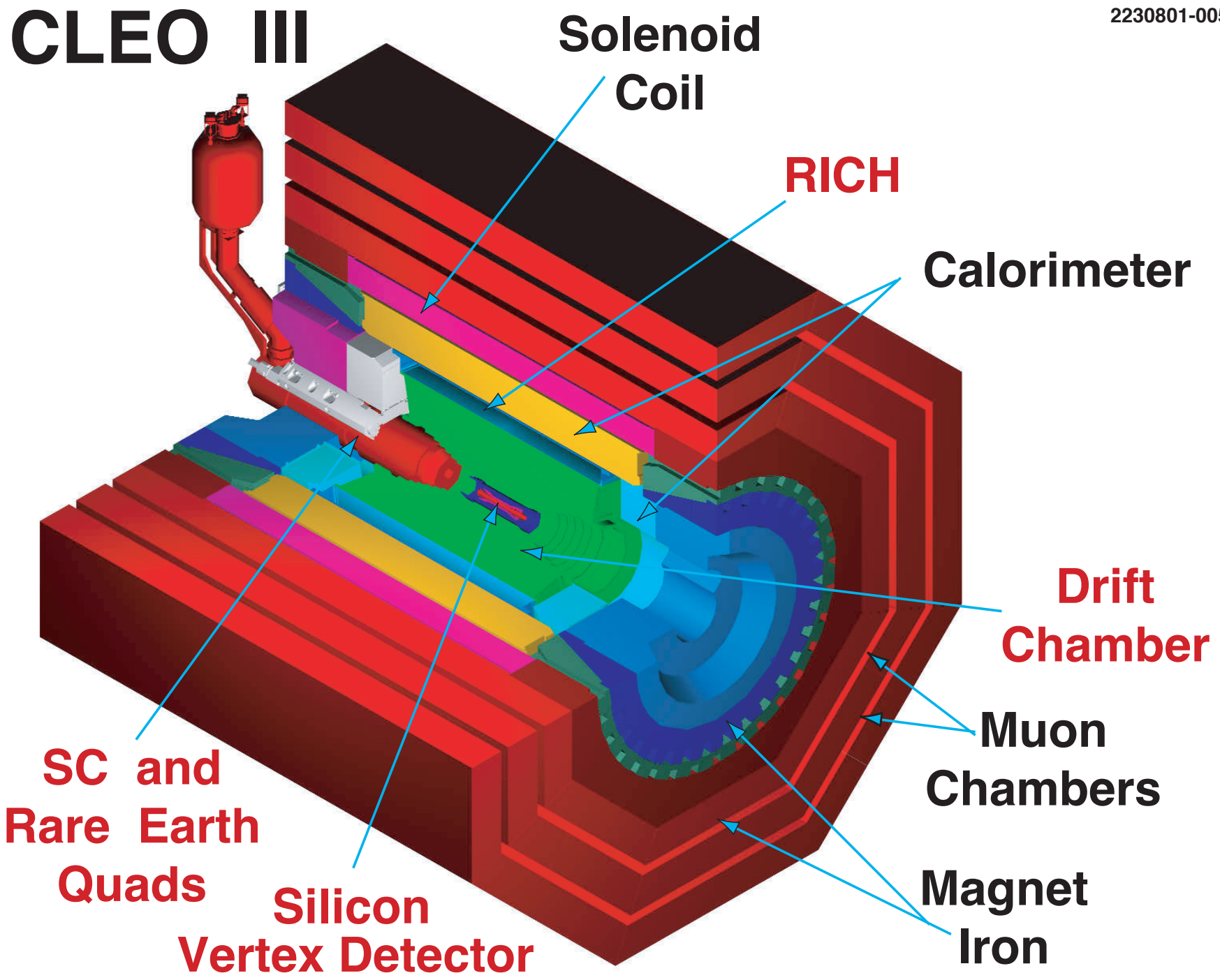
1) Measurement of $\Xi_c^0 \to pK^-K^-\pi^+$
(CLEO-III)

2) Form factors in $D^0 \to \{\pi^-, K^-\}e^+\nu$
(CLEO-III $\Rightarrow$ CLEO-c)

3) Disentangling glueballs and $q\bar{q}$ states
(CLEO-c)

XXXIX Rencontres de Moriond
QCD and High Energy Hadronic Interactions
28 March - 04 April, 2004


2230902-007
CLEO Integrated Luminosities
CLEO Physics
CLEO Upgrades
CESR Upgrades
10^9
10^8
10^7
10^6
10^5
10^4
$B\bar{B}$ / Year
1980
1985
1990
1995
2000
2005
Υ(1D)
RICH
New
Tracking
A_{CP} Limits
$B \to \pi\pi$
$D\bar{D}$ Mixing
Limit
2cm BP
Silicon
He-propane
CLEO III
$B \to K^*\gamma$
$b \to s\gamma$
$B \to K\pi$
$B \to \eta' K$
$B \to \pi/\rho\, \ell\nu$
CsI
3.5cm BP
CLEO II.V
9x5 Bunches
SC IR Quads
SC RF
9x4 Bunches
Crossing Angle
9X3 Bunches
($B\bar{B}$ Mixing)
$b \to u\, \ell\nu$
New
Tracking
CLEO II
1 IR
CLEO I.V
D_s
$b \to c\, \ell\nu$
B Decay
Υ(4S), Υ(5S)
CLEO I
Microbeta
7 Bunches
Pretzel Orbits


CLEO III
2230801-005
Solenoid Coil
RICH
Calorimeter
Drift Chamber
Muon Chambers
Magnet Iron
SC and Rare Earth Quads
Silicon Vertex Detector

1) Measurement of $\Xi_c^0 \to pK^-K^-\pi^+$

See **arXiv:hep-ex/0309020**, to appear in Physical Review D

Physics: The decay $\Xi_c^0 \to pK^-\bar{K}^\star(892)^0$ cannot proceed through external W decay, so it is "color suppressed".
$\Rightarrow$ Want to separate it from nonresonant four-body decays.

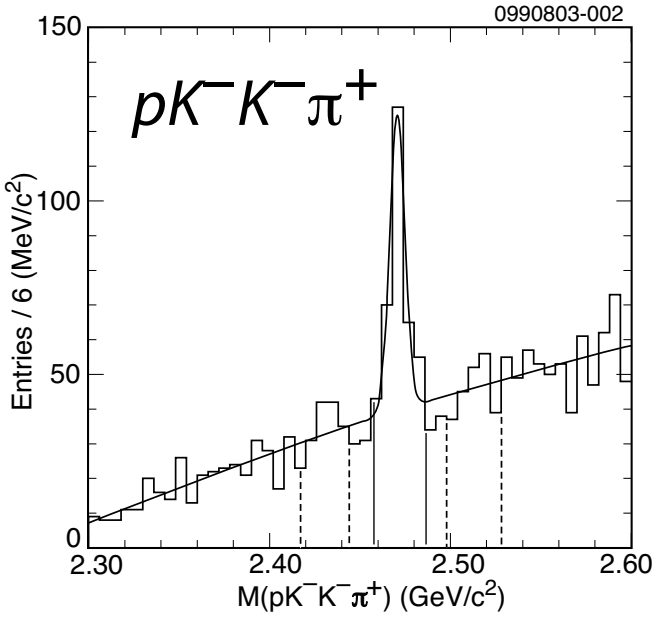
Measured $\Xi_c^0 \to pK^-K^-\pi^+$ rate relative to $\Xi_c^0 \to \Xi^-\pi^+$

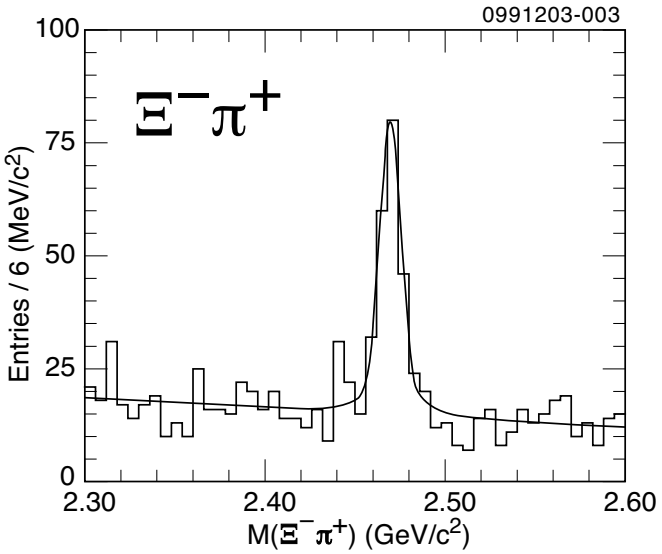
Needs extensive p, K, π particle identification made possible by RICH in CLEO-III

Only previous result: ACCMOR 1990 (four events, all $\bar{K}^\star$)

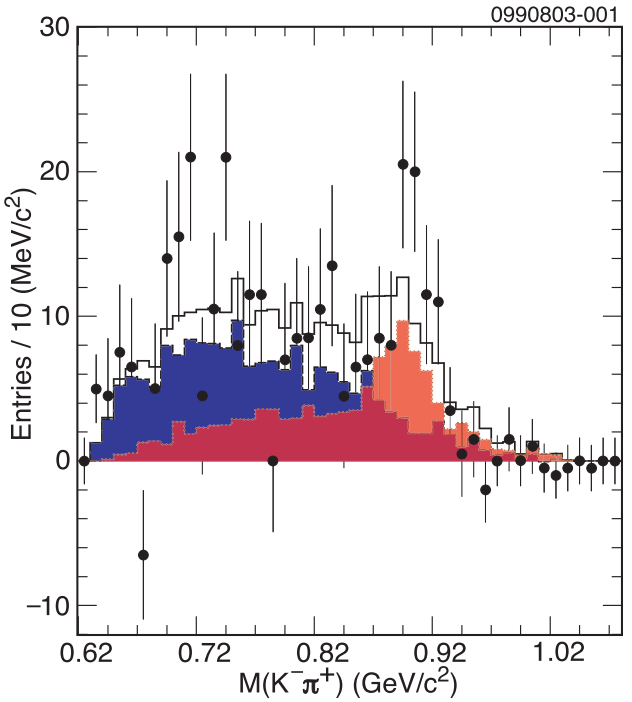
RESULTS: Ξ_c^0 Decay

Ξ_c^0 Decay modes





$K^-\pi^+$ mass distribution:

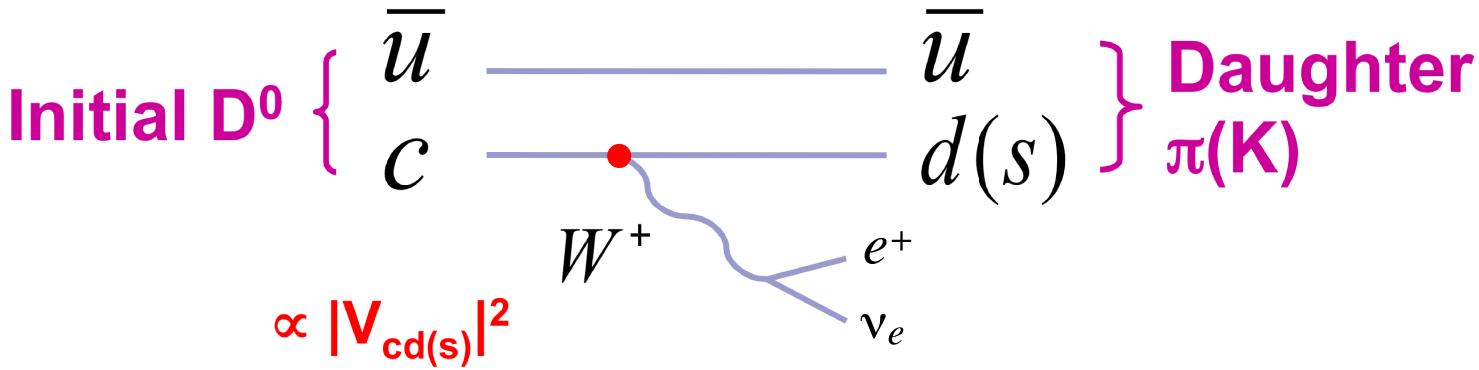


$$\mathcal{B}(\Xi_c^0 \to pK^-K^-\pi^+)/\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = 0.35 \pm 0.06 \pm 0.03$$

$$\mathcal{B}(\Xi_c^0 \to pK^-K^-\pi^+; \text{No } \bar{K}^\star)/\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = 0.21 \pm 0.04 \pm 0.02$$

2) Form Factors in $D^0 \to \{\pi^-, K^-\} e^+ \nu$

New CLEO-III analysis to be published soon.



For $q^\mu \equiv p^\mu(W^+)$ have $\dfrac{d\Gamma}{dq^2} = \dfrac{G^2}{24\pi^3} |V_{cq}|^2 \, p^3 \, |\mathcal{F}(q^2)|^2$

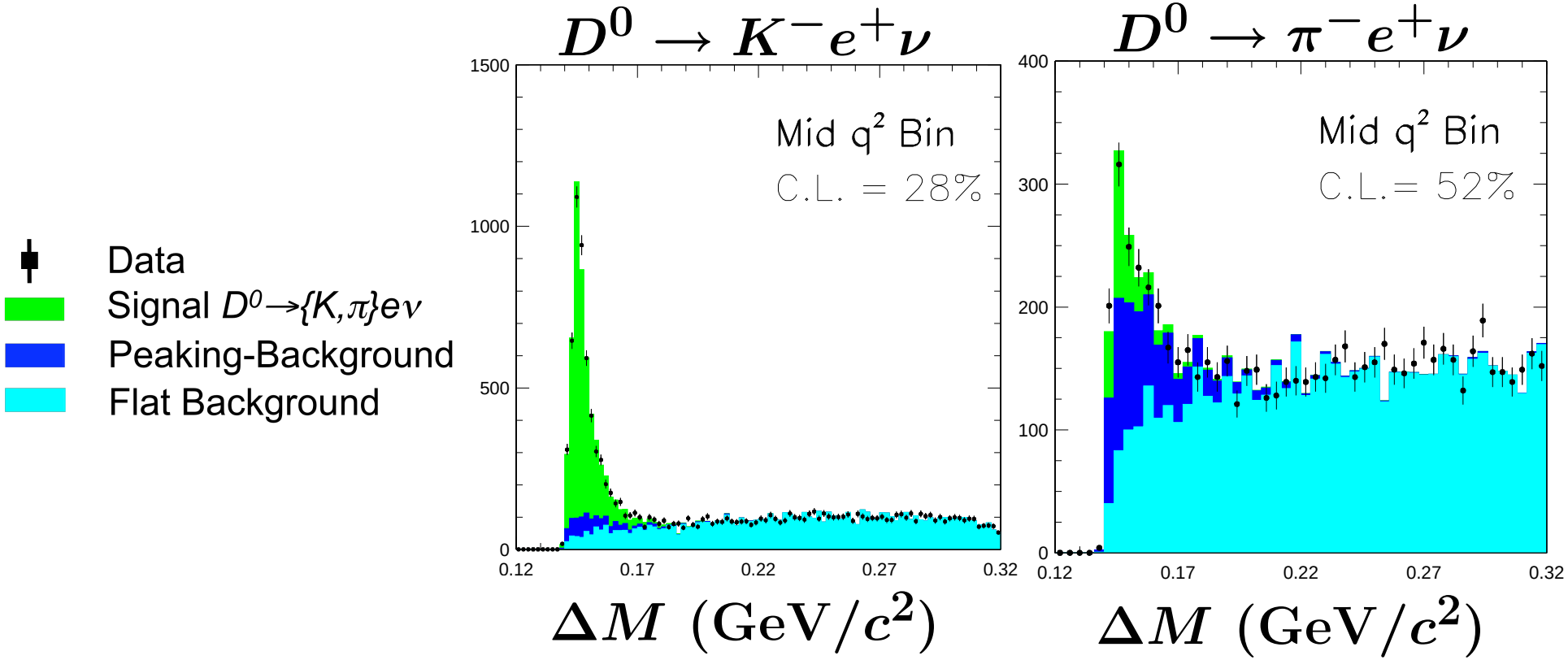
Note: First measurement of $D \to \pi e \nu$ form factor shape!

Plus: New result for $\mathcal{B}(D^0 \to \pi e \nu)/\mathcal{B}(D^0 \to K e \nu)$

Signal and Background in CLEO-III

Identify D^0 from $D^{\star +} \to \pi^+_{\rm slow} D^0$

Kinematic variable used is $\Delta M \equiv M(D^\star) - M(D)$

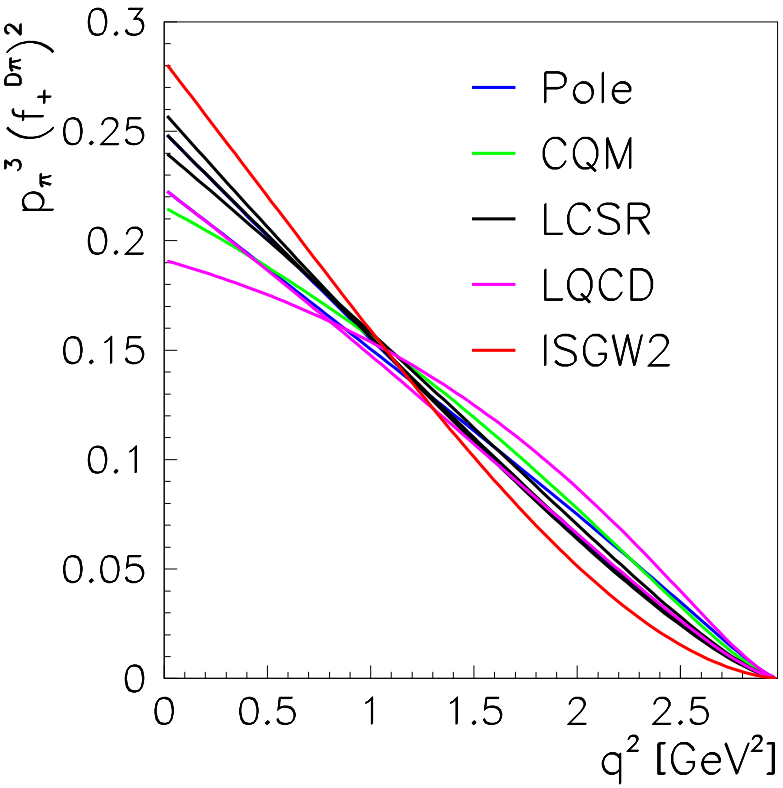


$\Rightarrow$ The challenge for $D \to \pi e \nu$ is significant!

RESULTS: $D^0 \to \pi^- e^+ \nu_e$ Normalized q^2 Distribution

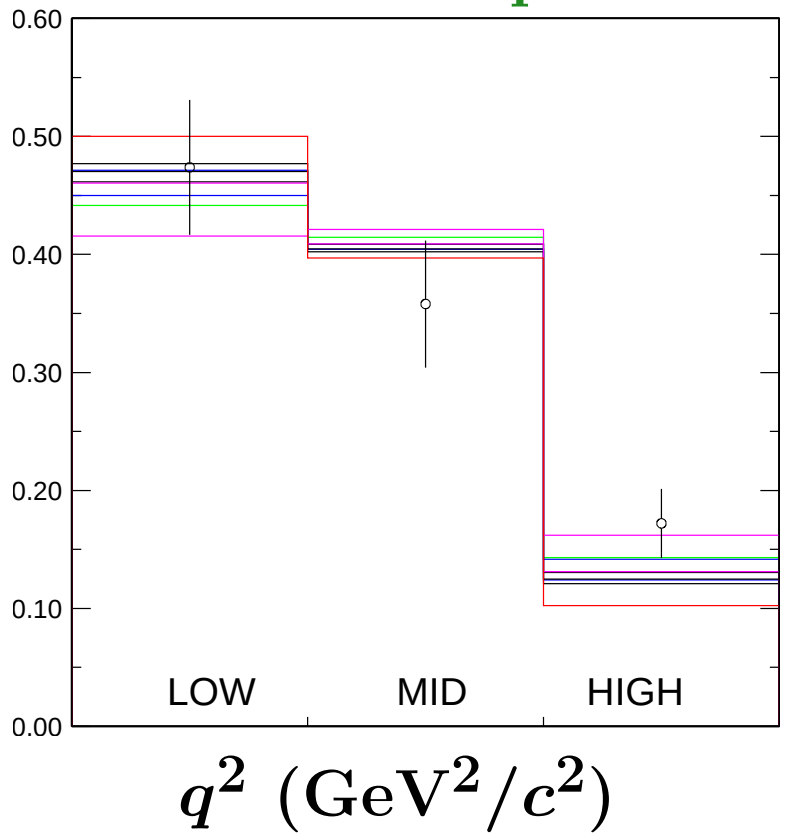
All results are preliminary!!

Form factor models



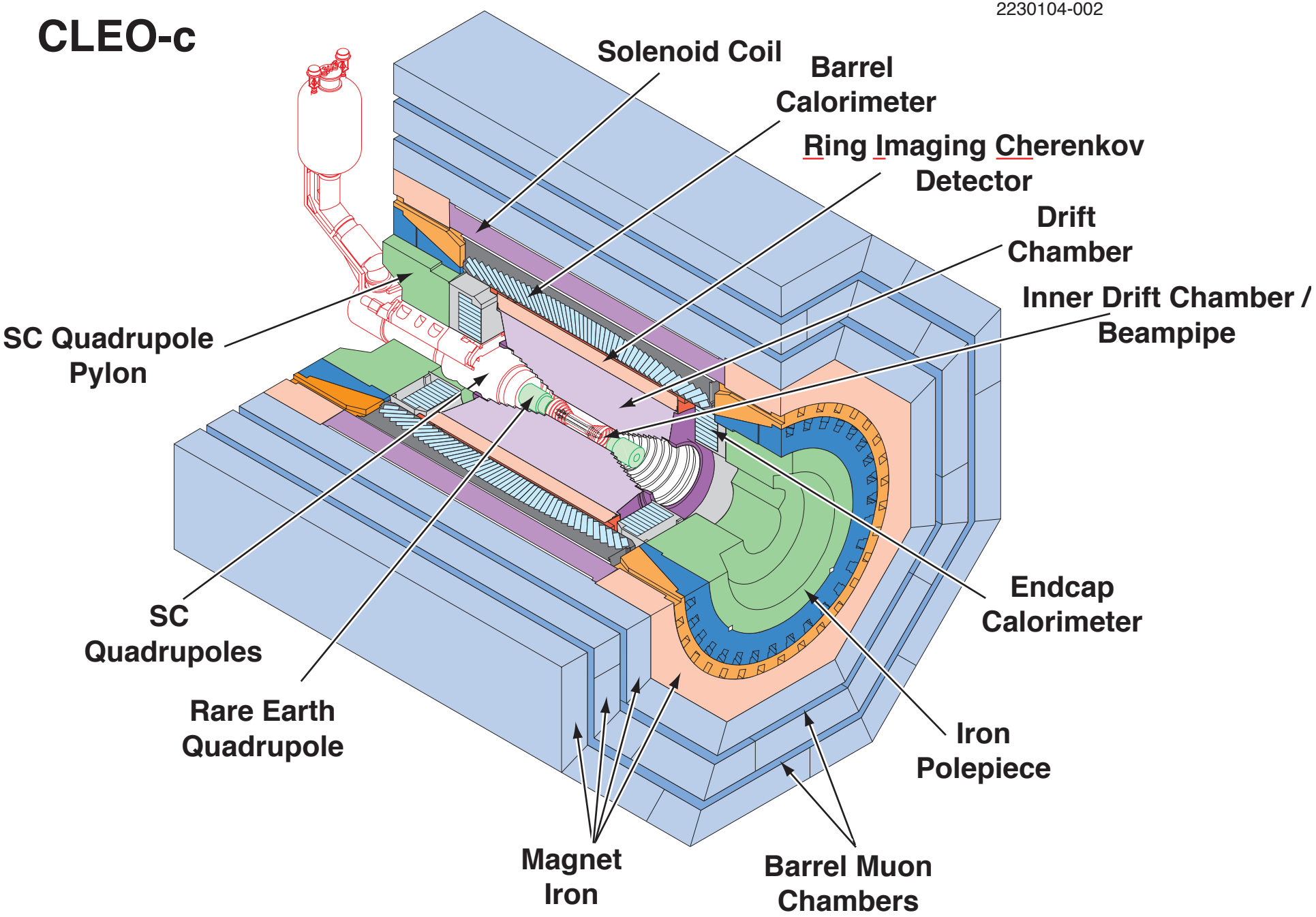
Binned data points

$$\frac{1}{\Gamma}\frac{d\Gamma}{dq^2} \times \text{Effic.}$$



Plus: $\mathcal{B}(D^0 \to \pi e \nu)/\mathcal{B}(D^0 \to K e \nu) = 0.097 \pm 0.010 \pm 0.010$

CLEO-c


2230104-002
Solenoid Coil
Barrel Calorimeter
Ring Imaging Cherenkov Detector
Drift Chamber
Inner Drift Chamber / Beampipe
SC Quadrupole Pylon
SC Quadrupoles
Rare Earth Quadrupole
Endcap Calorimeter
Iron Polepiece
Magnet Iron
Barrel Muon Chambers

The CLEO-c Program

Prologue: Completed $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$, $\Upsilon(5S)$, $\Lambda_b\bar{\Lambda}_b$ runs, and short runs carried out at $\psi'(3686)$, $\psi''(3770)$, ...

Dedicated Running in ∼1 Year Blocks

Act I: $\psi(3770)$ 3 fb^{-1} ⇒ 30M Events (for $\sigma_{D\bar{D}} = 10$ nb)
⇒ 6M Tagged D decays

Act II: $\sqrt{s} \approx 4.1$ GeV 3 fb^{-1} ⇒ 300K Tagged D_s decays

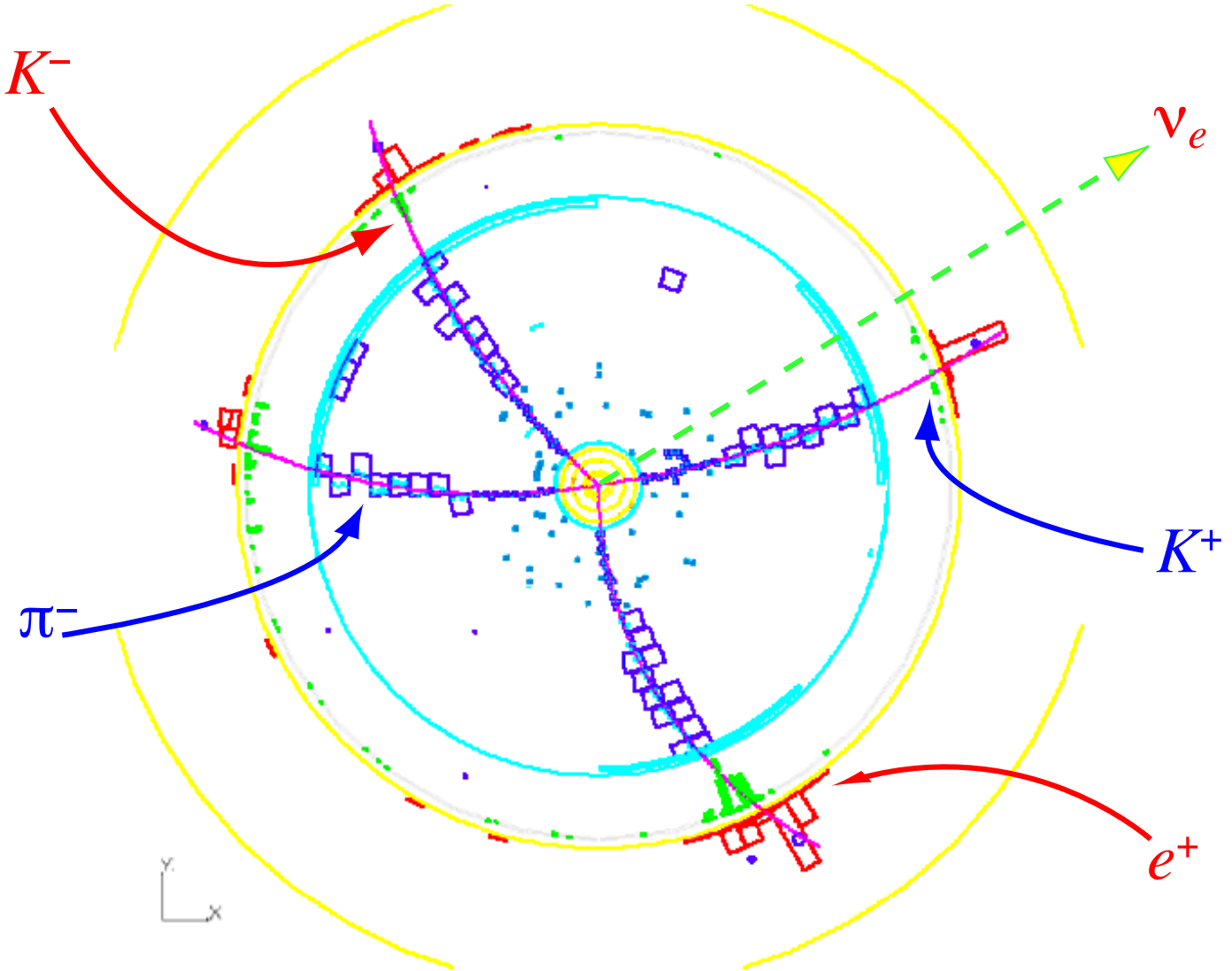
Act III: $J/\psi(3097)$ 1 fb^{-1} ⇒ 1 Billion J/ψ decays

Act I is already underway!

Epilogue: $\psi'(3686)$, R, ... depending on time and resources

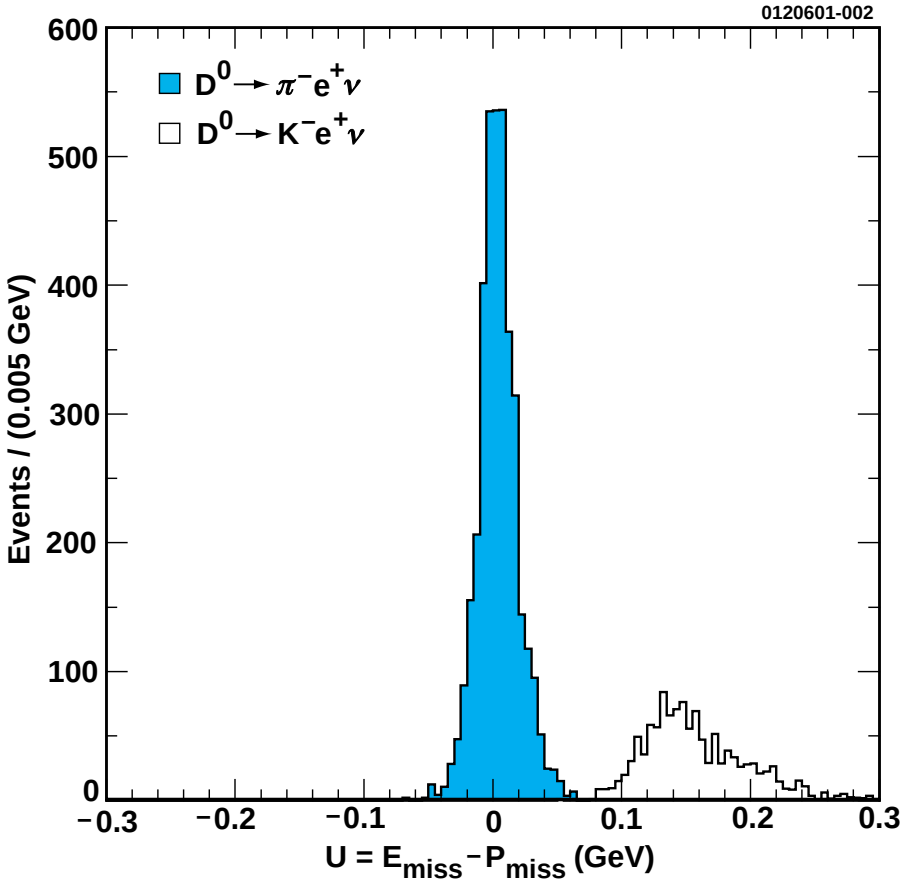
CLEO-c event: $e^+e^- \to \psi''(3770) \to D^0\bar{D}^0$

$D^0 \to K^-e^+\nu_e$ $\quad$ $\bar{D}^0 \to K^+\pi^-$

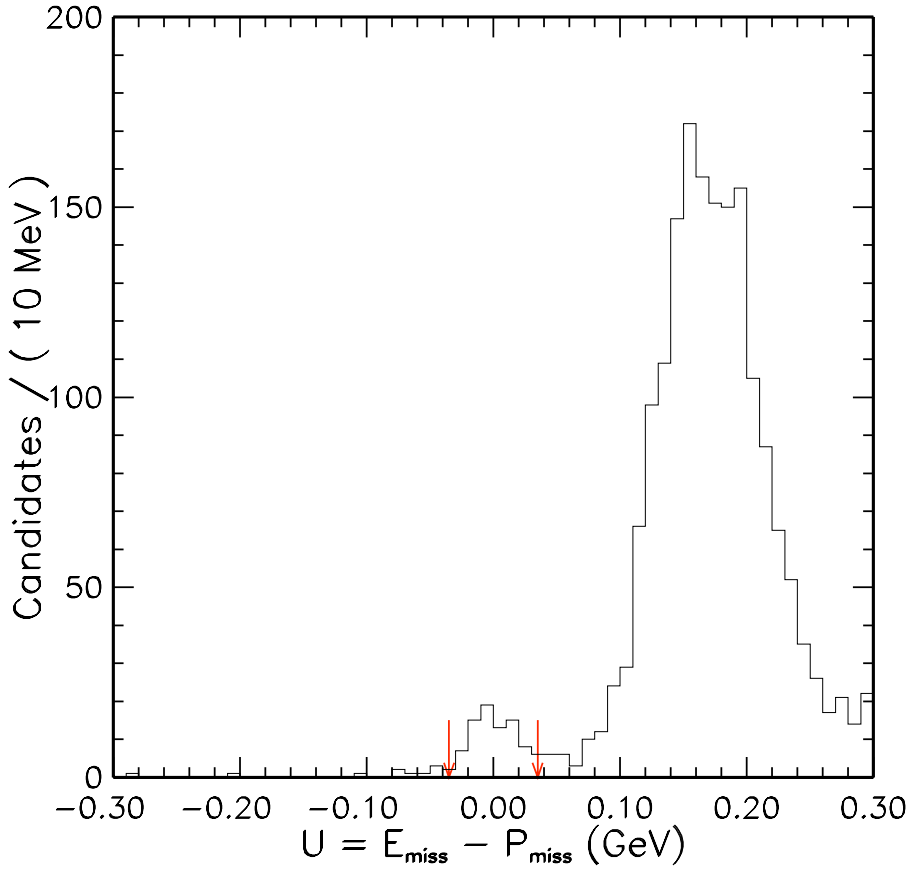


Signal and Background for $D^0 \to \pi^- e^+ \nu$ in CLEO-c

Monte Carlo
Assumed 1 fb^{-1}
Particle ID cuts applied



Data (Preliminary!)
Analyzed 60 pb^{-1}
No particle ID cuts (yet)



3) Disentangling Glueballs and $q\bar{q}$ States

Radiative J/ψ decay is an excellent glueball filter

$$J/\psi \to \gamma gg \to \gamma + \text{glueball}$$

Lattice QCD says the lightest glueball is a scalar meson with a mass between 1500 and 1700 MeV/c^2.

The quark model says there are two scalar mesons in this mass region (i.e. $|u\bar{u} + d\bar{d}\rangle \equiv |n\bar{n}\rangle$ and $|s\bar{s}\rangle$).

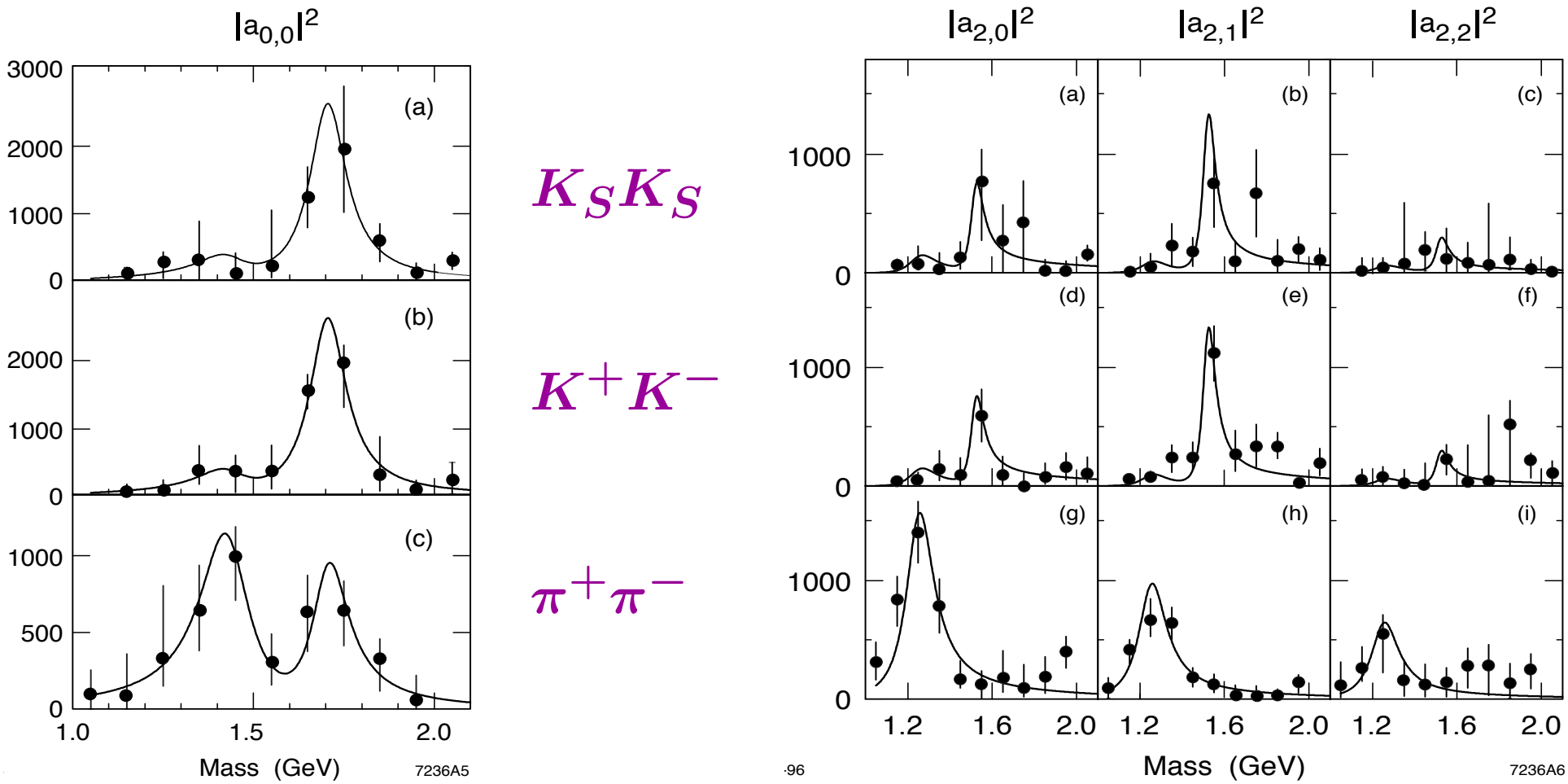
Three states have been observed:

$$f_0(1370), f_0(1500), f_0(1710)$$

$\Rightarrow$ ***What is the mixture of $q\bar{q}$ and glueball?***

Mark-III (SPEAR): 6×10^6 J/ψ

$J/\psi \to \gamma X$, where $X \to \ldots$



$K_S K_S$

$K^+ K^-$

$\pi^+ \pi^-$

Data Points: A Bin-by-Bin (i.e. Mass Independent) Fit
Solid Lines: A Mass Dependent Fit to the Data Points

No sign of the $f_0(1500)$?

Radiative Decays as a Probe of $q\bar{q}$-Glueball Mixing

F. E. Close, et al., Phys. Rev. D 67, 074031 (2003)

$$M(glueball) < M(n\bar{n}) \quad \equiv \text{“L”}$$
$$M(n\bar{n}) < M(glueball) < M(s\bar{s}) \quad \equiv \text{“M”}$$
$$M(glueball) > M(s\bar{s}) \quad \equiv \text{“H”}$$

Radiative Decay Widths in keV							Γ_{Tot}
	$f_0 \to \gamma\rho(770)$			$f_0 \to \gamma\phi(1020)$			MeV
State	L	M	H	L	M	H	
$f_0(1370)$	443	1121	1540	8	9	32	$\sim$300
$f_0(1500)$	2519	1458	476	9	60	454	109
$f_0(1710)$	42	94	705	800	718	78	125

Excellent discrimination!

$\Rightarrow$ Expect $\mathcal{B}(f_0 \to \gamma V) \approx 10^{-2}$ to 10^{-4}.
For $\mathcal{B}(J/\psi \to \gamma f_0) \approx 10^{-3}$ we should acquire
$10,000$ to 100 events for 10^9 J/ψ.

Summary and Outlook

- **CLEO-III is still producing results**

  This Conference: **M. Shepherd and J. Duboscq**
  See also: M. Dubrovin, Moriond QCD 2003,
  including $D \to \pi\pi\pi$, $D \to K\pi\pi$, $D \to KK\pi$, ...

- **CLEO-c well underway towards 3 fb^{-1} at $\psi''(3770)$**

  Large sample of *clean* $D\bar{D}$ pairs
  Hadronic *and* electroweak physics analyses started

- **Strong future program for CLEO-c**

  $\gamma D\bar{D}$ and $D_s^+ D_s^-$ production
  Goal of 10^9 J/ψ events
  Other physics opportunities

Stay Tuned!

Thank you!