

Lattice 2005



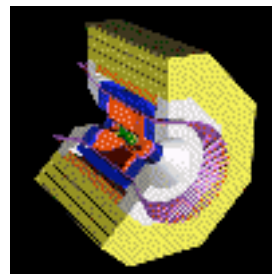
CLEO-c *confronts* High Precision Lattice QCD

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for the CLEO-c Collaboration

XXIII International Symposium on Lattice Field Theory
School of Mathematics, Trinity College, Dublin
25th-30th July 2005



Rensselaer

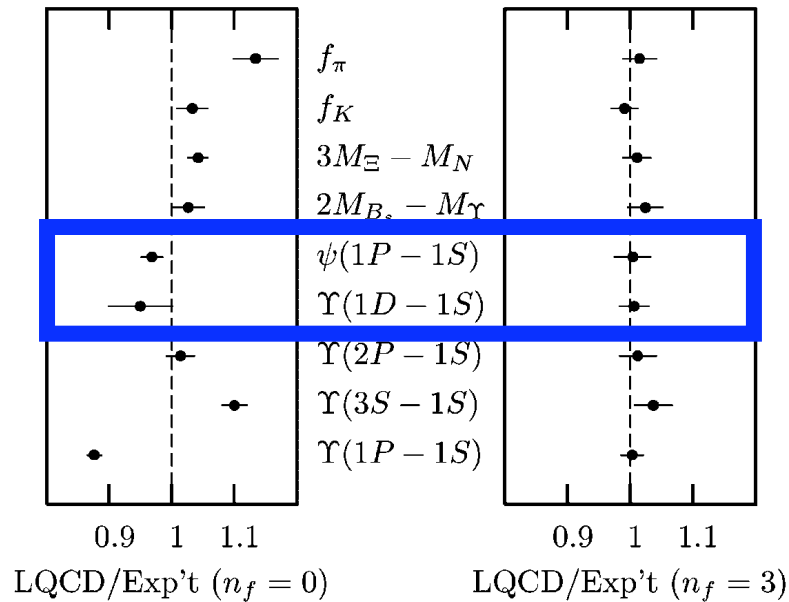


Outline

Focus on issues specific to Lattice QCD

- Latest Results: $D^+ \rightarrow \mu^+ \nu_\mu$
 - ★ Related and Brand New: Γ_{ee} for $\Upsilon(nS)$
- Latest Results: D^+, D^0 semi-leptonic decay
- Summary: Heavy quarkonium masses
- The Future
 - Increased precision on D decays
 - Data taking for D_s decays
 - Glueballs revisited

Confrontations in this Talk

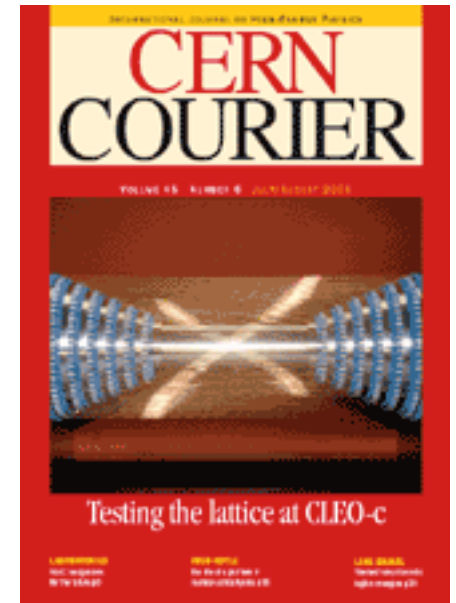


Results from recent CLEO runs prior to taking data at the $\psi(3770)$.

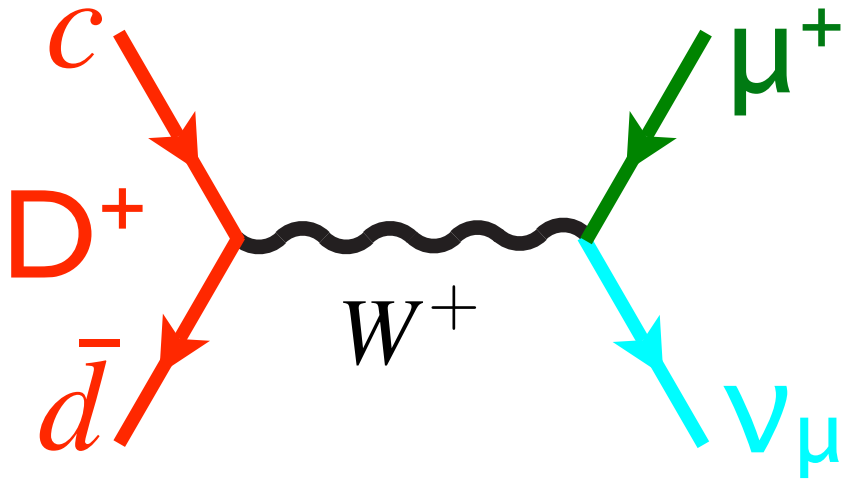
$$\left(\begin{array}{ccc}
 V_{ud} & V_{us} & V_{ub} \\
 \pi \rightarrow l\nu & K \rightarrow l\nu & B \rightarrow \pi l\nu \\
 & K \rightarrow \pi l\nu & \\
 V_{cd} & V_{cs} & V_{cb} \\
 D \rightarrow l\nu & D_s \rightarrow l\nu & B \rightarrow D l\nu \\
 D \rightarrow \pi l\nu & D \rightarrow K l\nu & \\
 V_{td} & V_{ts} & V_{tb} \\
 \langle B_d | \bar{B}_d \rangle & \langle B_s | \bar{B}_s \rangle &
 \end{array} \right)$$

Very recent results.

Goals of future run plans.



Latest Results: $D^+ \rightarrow \mu^+ \nu_\mu$



$$\Gamma = \frac{G_F^2}{8\pi} m_\mu^2 M_{D^+} \left(1 - \frac{m_\mu^2}{M_{D^+}^2} \right)^2 \times f_{D^+}^2 |V_{cd}|^2$$

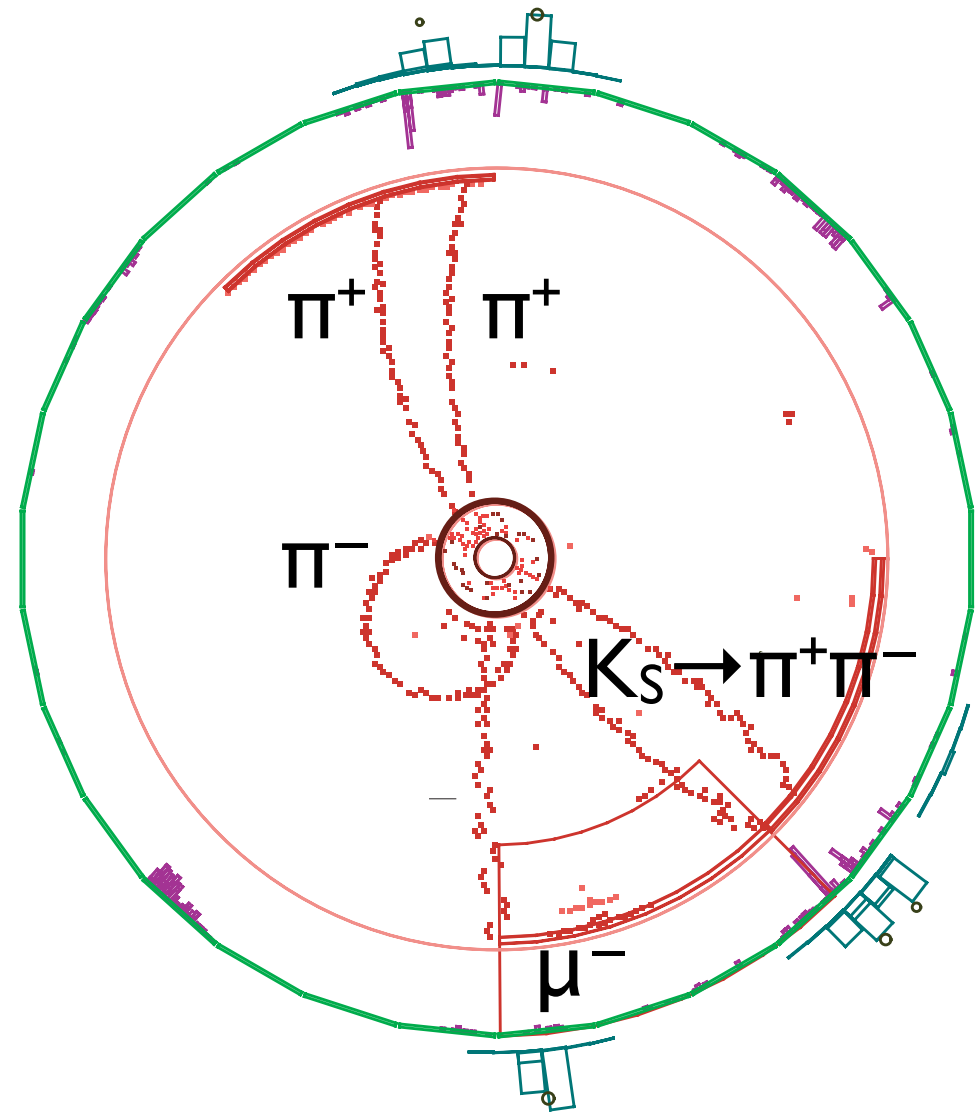
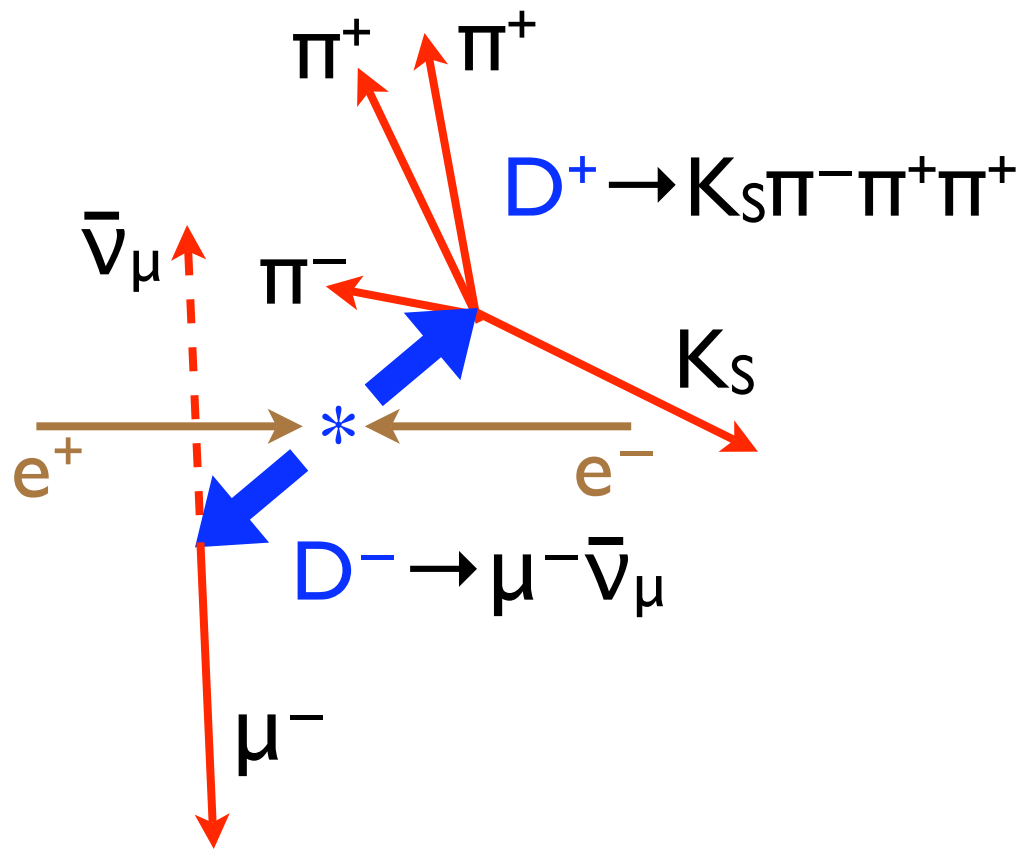
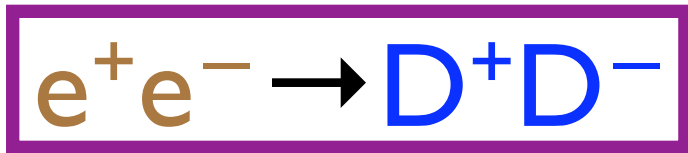
A Difficult Measurement!

- Small branching ratio
- Need to reconstruct “missing” neutrino
- Backgrounds from many sources
- Precision is important!

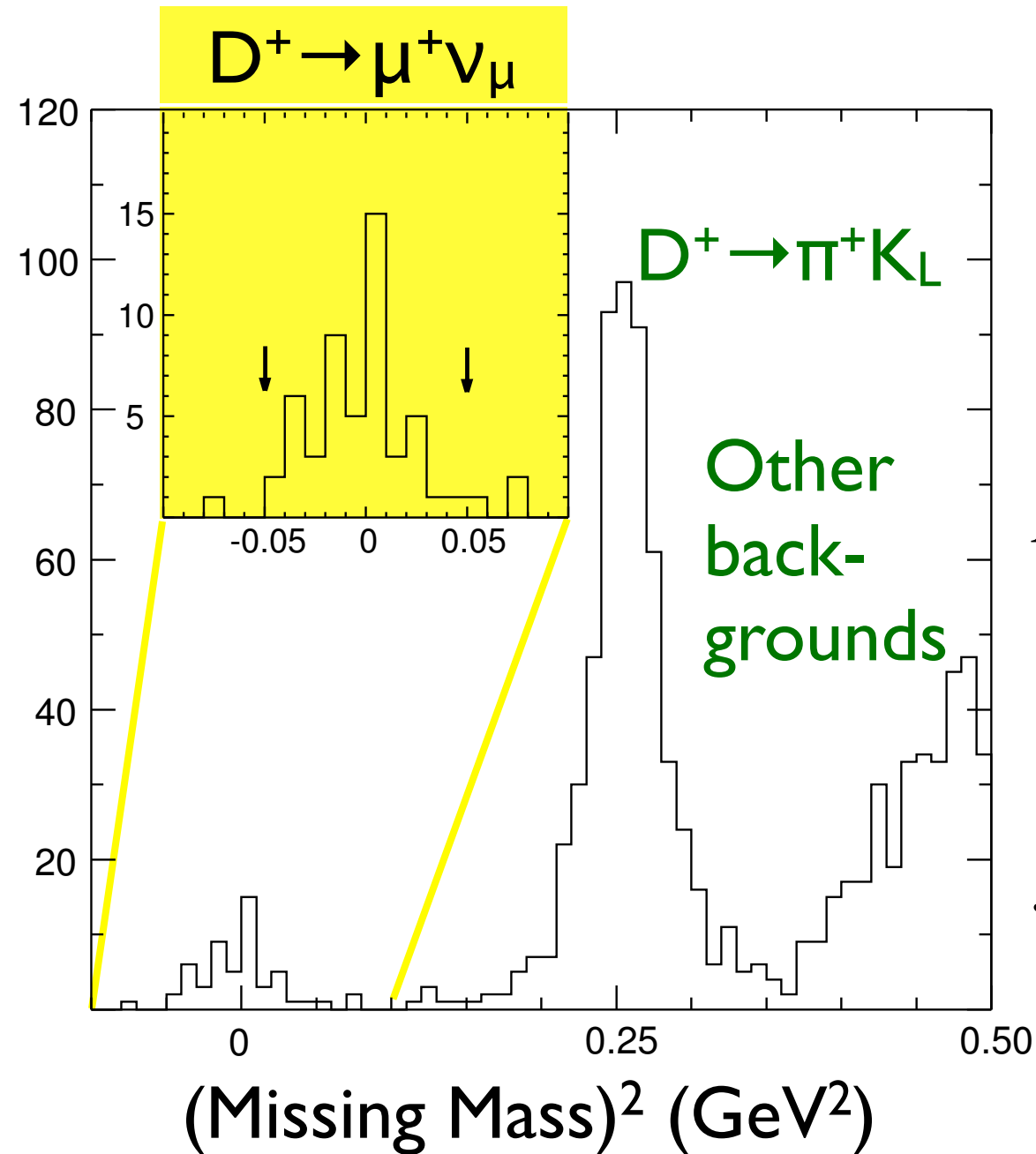
An opportunity almost ideal for CLEO-c!

The Special Contribution of CLEO-c

Decays of “Tagged” D-mesons using $\psi(3770)$ Data Runs



Results (*Preliminary*)



With **280 pb⁻¹** of data, we observe 50 events with a background of 3.

Branching Ratio

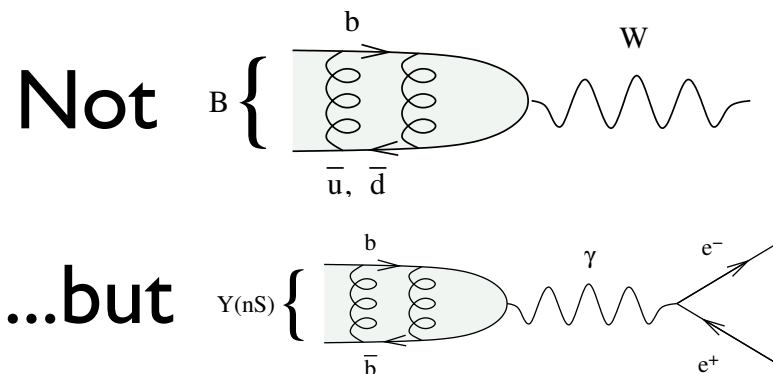
$$B(D^+ \rightarrow \mu^+ \nu_\mu) = (4.45 \pm .67^{+.29}_{-.36}) \times 10^{-4}$$

Decay Constant

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

More data to come!

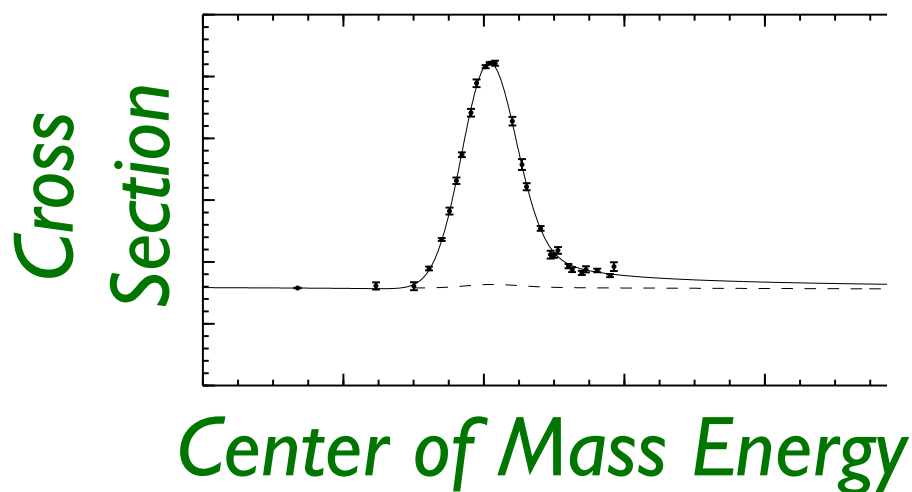
Related *and* Brand New: Γ_{ee} for $\Upsilon(nS)$



Tour de force of statistical and systematic precision!

Preliminary Results

Get widths by measuring the total cross section in e^+e^- annihilation:



$$\Gamma_{ee}(1S) = 1.336 \pm 0.009 \pm 0.019 \text{ keV}$$

$$\Gamma_{ee}(2S) = 0.616 \pm 0.010 \pm 0.009 \text{ keV}$$

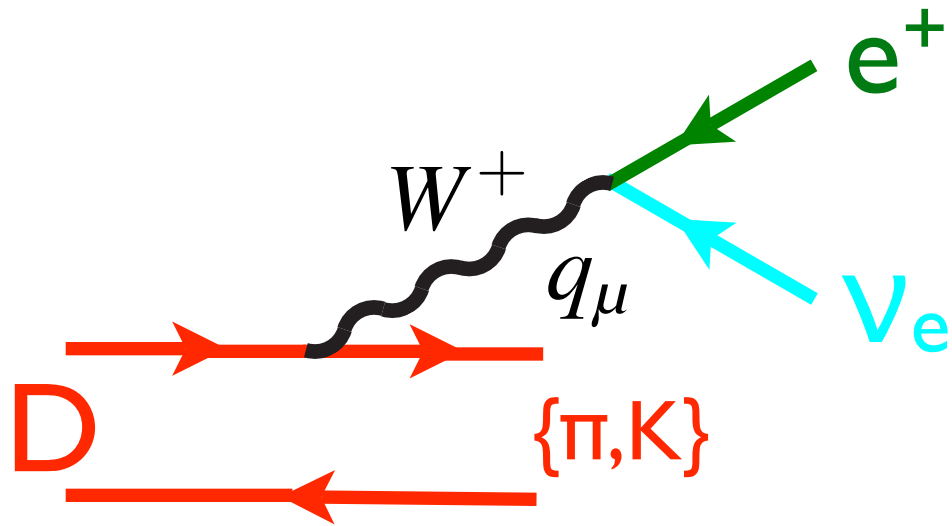
$$\Gamma_{ee}(3S) = 0.425 \pm 0.009 \pm 0.006 \text{ keV}$$

$$\Gamma_{ee}(2S)/\Gamma_{ee}(1S) = 0.461 \pm 0.008 \pm 0.003$$

$$\Gamma_{ee}(3S)/\Gamma_{ee}(1S) = 0.318 \pm 0.007 \pm 0.002$$

$$\Gamma_{ee}(3S)/\Gamma_{ee}(2S) = 0.690 \pm 0.019 \pm 0.006$$

Latest Results: $D \rightarrow \{\pi, K\} e^+ \nu_e$

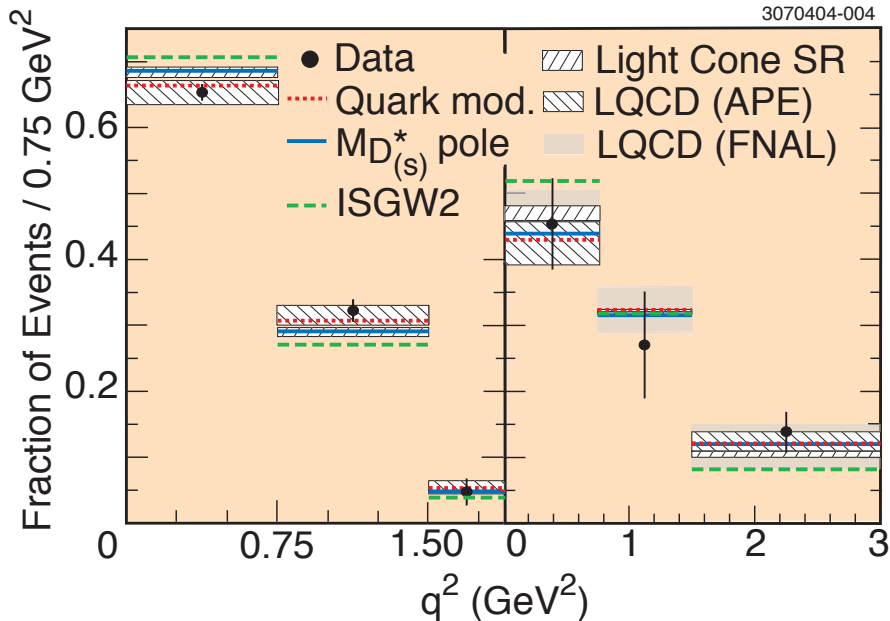
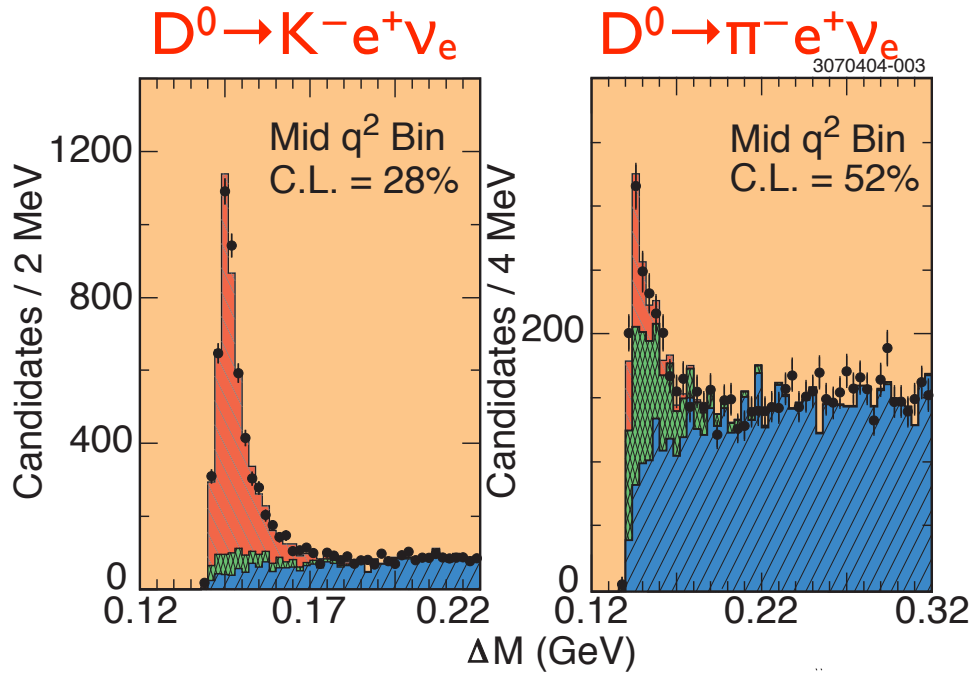


A Key Measurement!

- Needed to “climb the ladder” to V_{ub}
- Form factors are the main uncertainties
- CLEO-c eventually aims for precision form factor results

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{c\{d,s\}}|^2 p_{\{\pi,K\}}^3 \left| f^{\{\pi,K\}}(q^2) \right|^2$$

The Need for Tagged D Mesons



Recent result from CLEO-III
 (e^+e^- annihilation at 10 GeV)
 G.S. Huang, et al, PRL 94(2005)011802

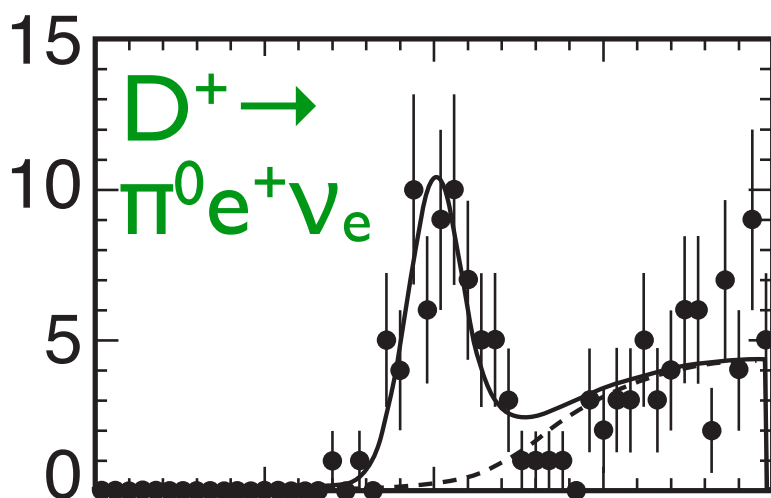
You can make lots of D's at high energy, but they are difficult to isolate cleanly.

Small signal with lots of different kinds of background.

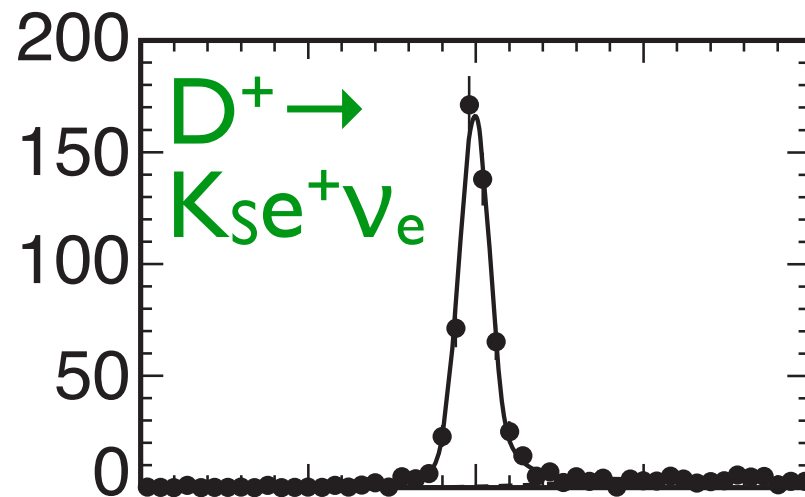
Another excellent opportunity for CLEO-c

Results (*Preliminary*)

The signal is cleanly separated from the background



$$U = E_{miss} - cP_{miss}$$



$$U = E_{miss} - cP_{miss}$$

Branching Ratios (%)

$$D \rightarrow \pi e^+ \nu_e$$

$$D \rightarrow K e^+ \nu_e$$

D^+	$0.44 \pm 0.06 \pm 0.03$	$8.71 \pm 0.38 \pm 0.37$
D^0	$0.262 \pm 0.025 \pm 0.008$	$3.44 \pm 0.10 \pm 0.10$

More Results (*Preliminary*)

Values derived from branching ratio measurements

$$B(D^0 \rightarrow \pi^- e^+ \nu_e) / B(D^0 \rightarrow K^- e^+ \nu_e) = 0.076 \pm 0.008 \pm 0.002$$

$$\Gamma(D^0 \rightarrow K^- e^+ \nu_e) / \Gamma(D^+ \rightarrow \bar{K}^0 e^+ \nu_e) = 1.00 \pm 0.05 \pm 0.04$$

$$\Gamma(D^0 \rightarrow \pi^- e^+ \nu_e) / 2 \times \Gamma(D^+ \rightarrow \pi^0 e^+ \nu_e) = 0.75^{+0.14}_{-0.11} \pm 0.04$$

Form factor measurements are on the way.

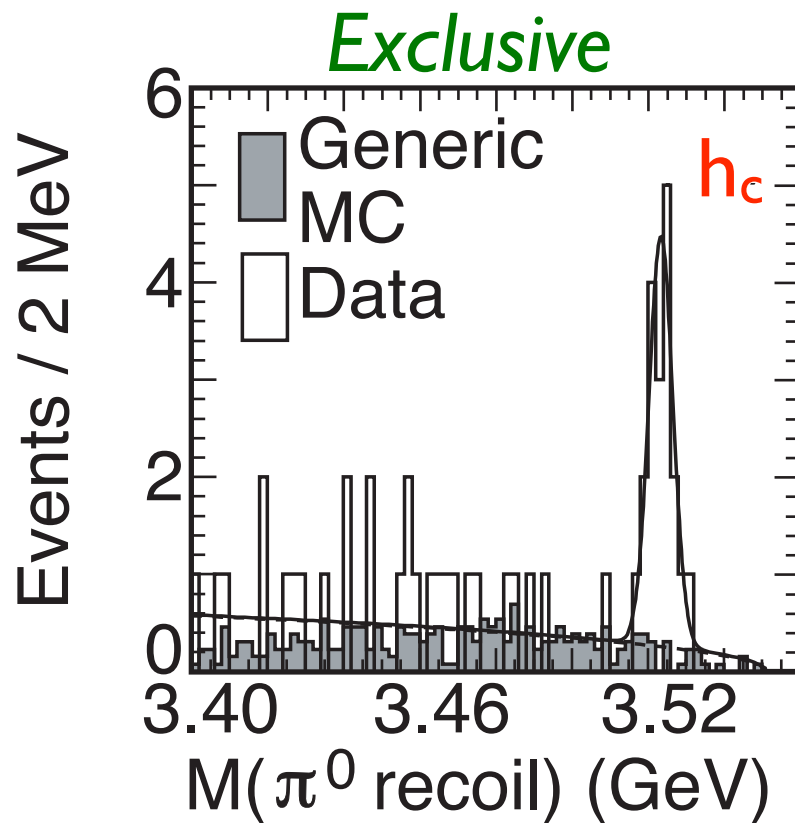
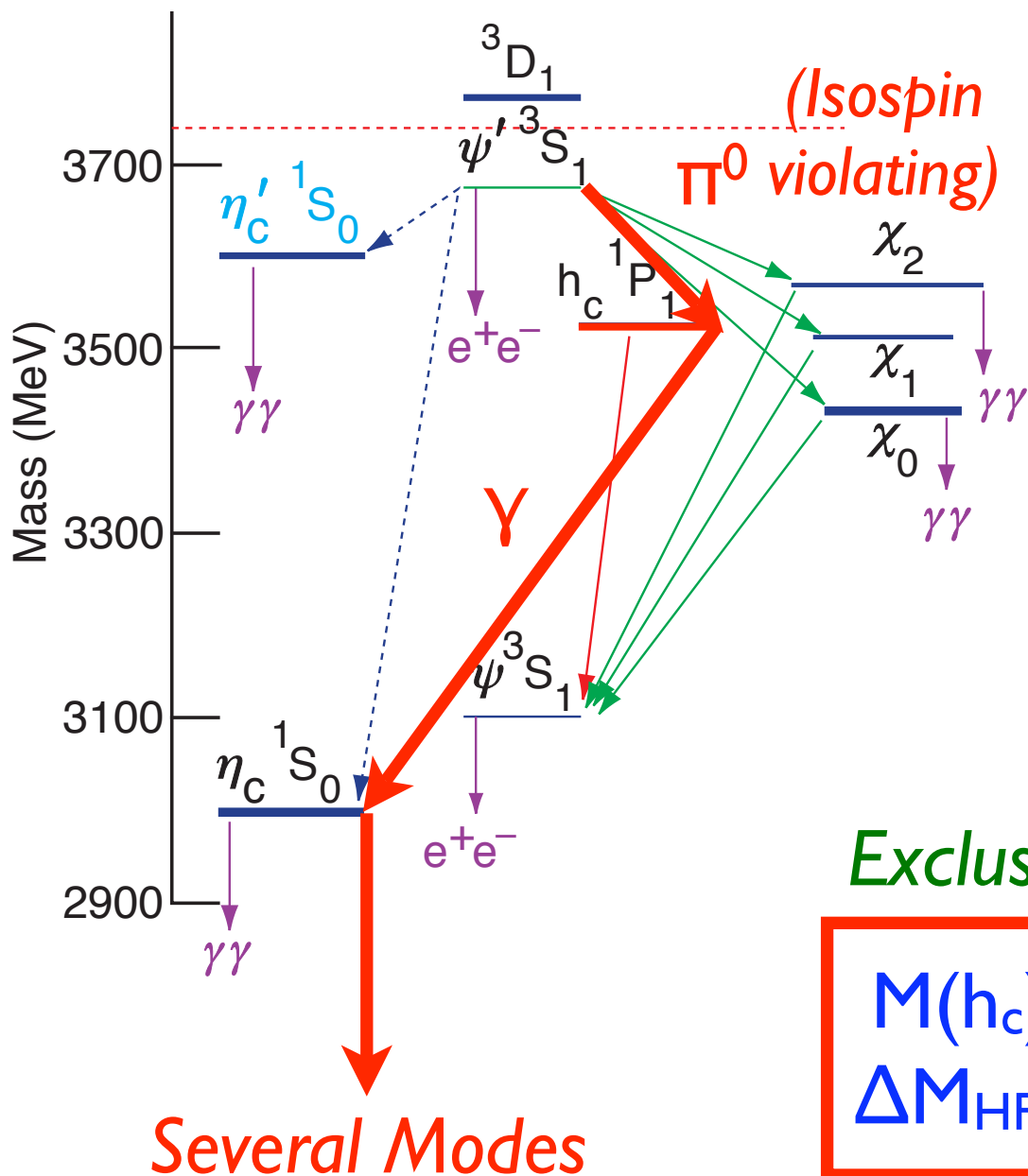
Note: All these results based on 56 pb⁻¹ data sample.

Summary: Heavy quarkonium masses

All these results are based on non $\psi(3770)$ running

- Observation of the 1P_1 charmonium state h_c
- First observation of an $\Upsilon(1D)$ state
- Observation of η_c and η'_c in the two photon annihilation reaction
- New measurements of radiative transition rates for $\psi(2S) \rightarrow \gamma \chi_{cj}$ and $\gamma \eta_c$

Observation of 1P_1 Charmonium (h_c)

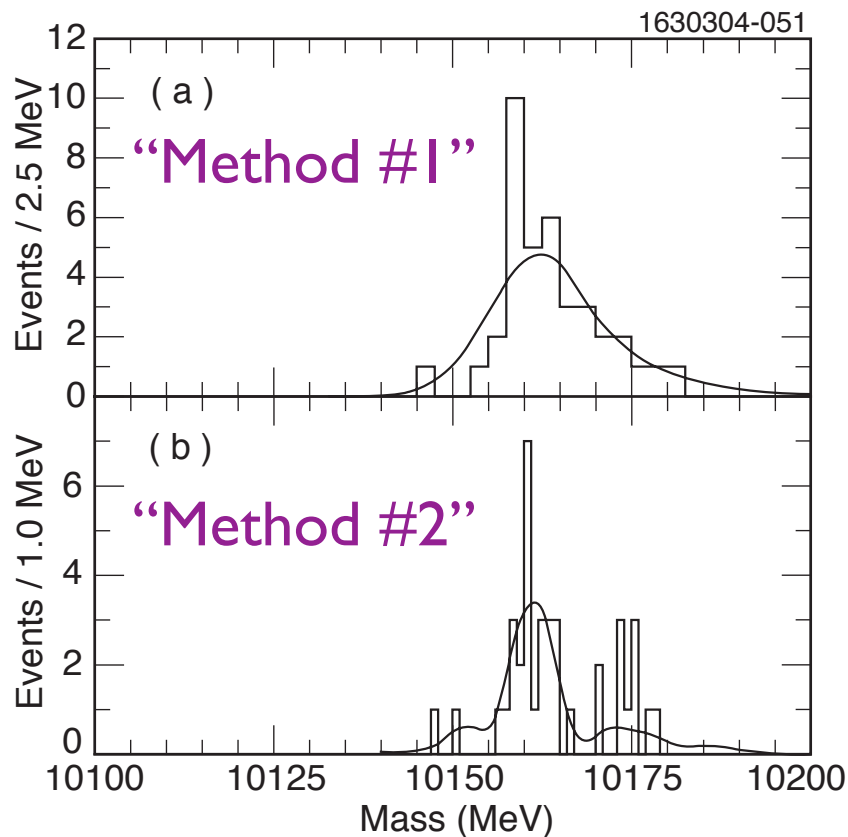
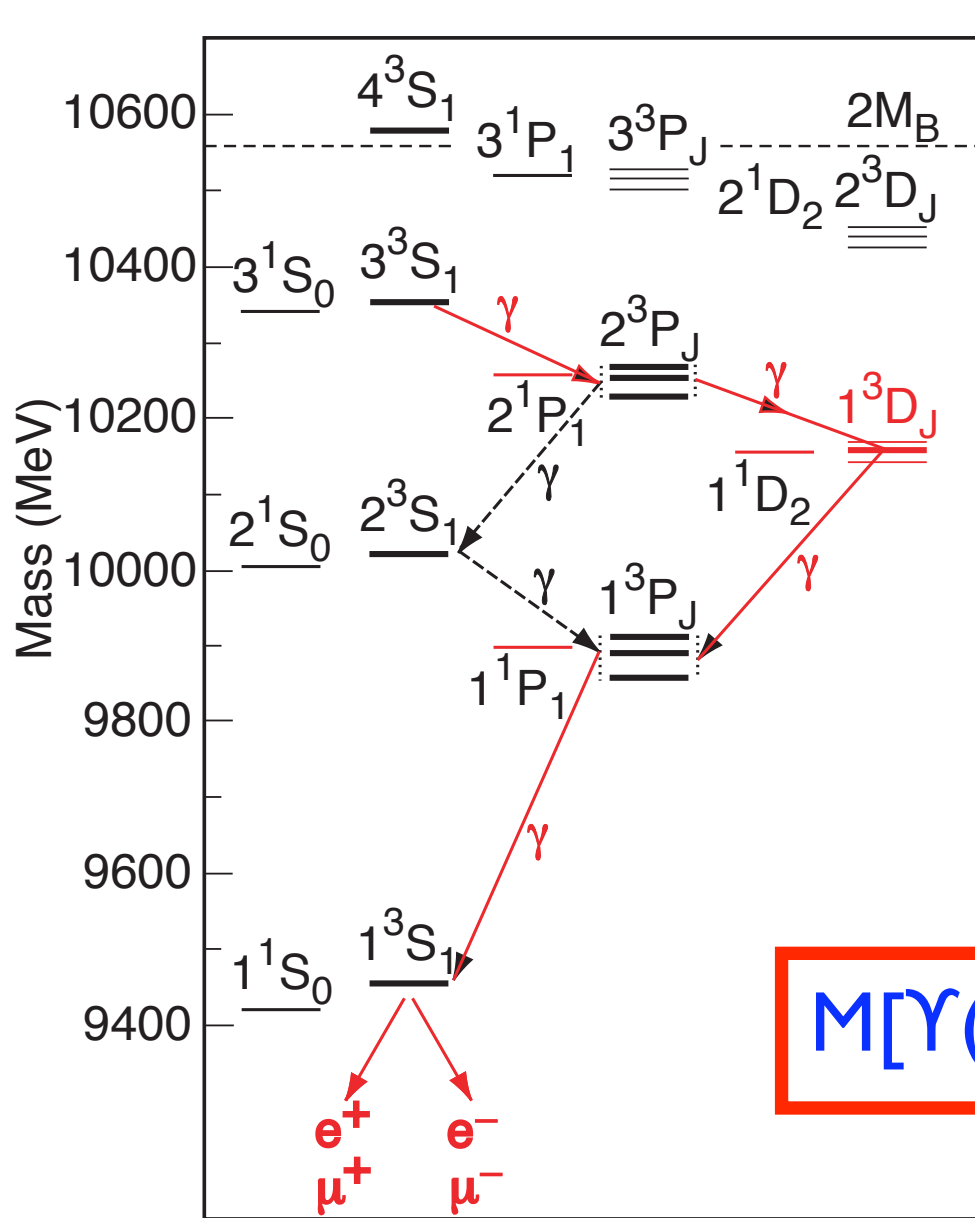


Exclusive and Inclusive average

$$M(h_c) = 3524.4 \pm 0.6 \pm 0.4 \text{ MeV}$$

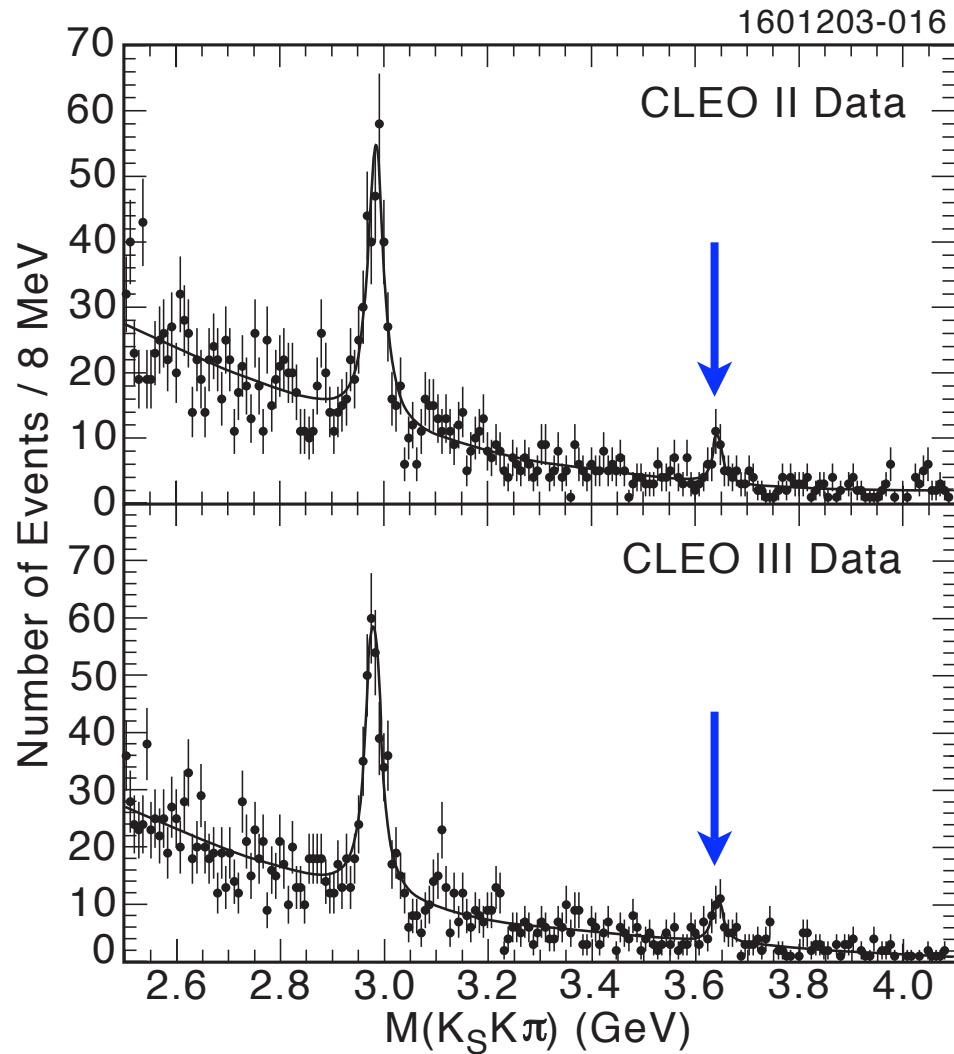
$$\Delta M_{\text{HF}}(1P) = 1.0 \pm 0.6 \pm 0.4 \text{ MeV}$$

First observation of an $\Upsilon(1D)$ state



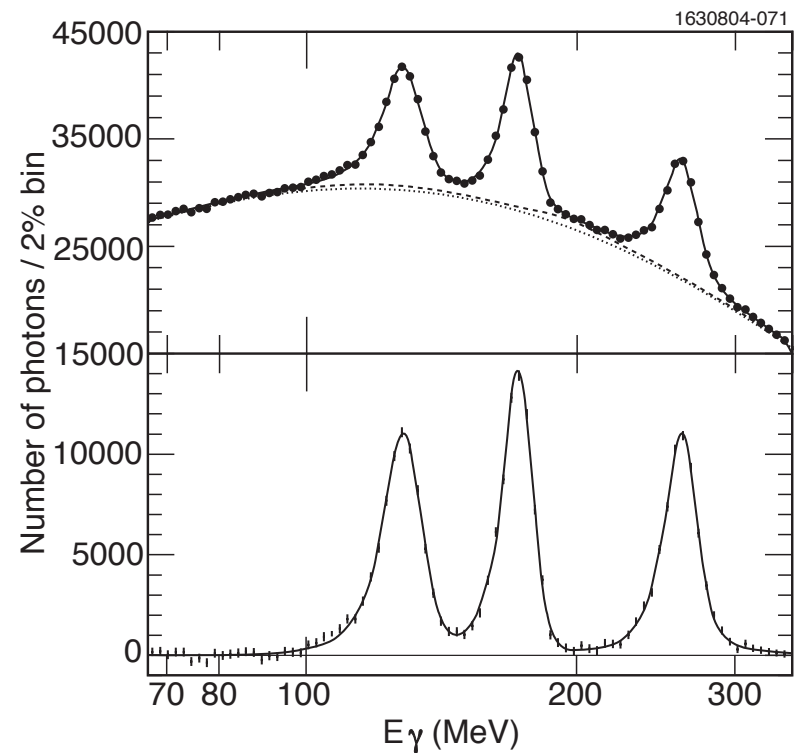
$$M[\Upsilon(1^3D_2)] = 10161.1 \pm 0.6 \pm 1.6 \text{ MeV}$$

η_c and η'_c



$$M(\eta'_c) = 3642.9 \pm 3.1 \pm 1.5 \text{ MeV}$$

$\psi(2S) \rightarrow \gamma \chi_{cj}$ (and $\gamma \eta_c$)



Yields EI transition rates with 5-7% uncertainties, limited by systematics.

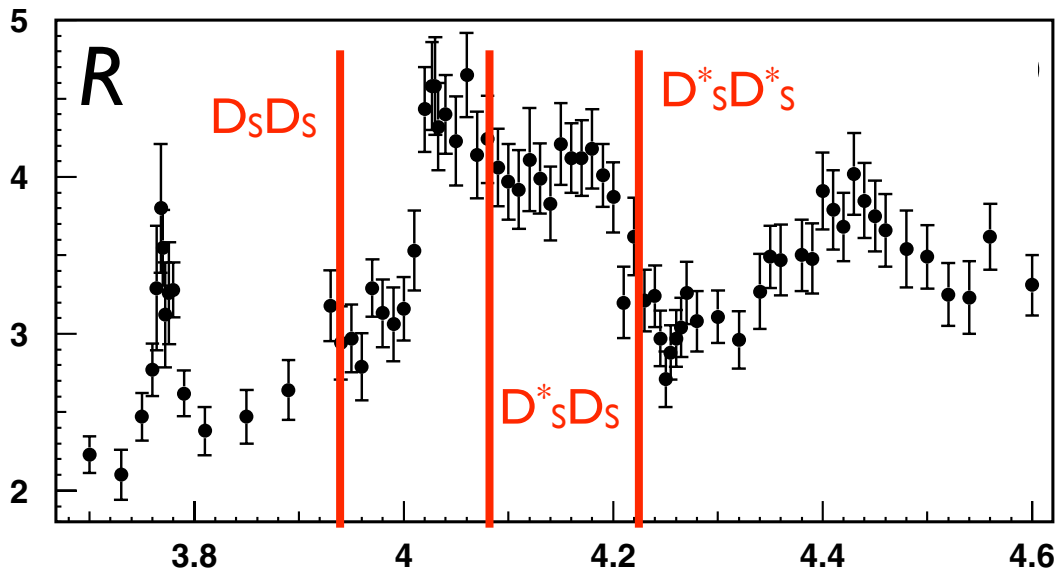
The Future

Increased precision on D decays

- Current data sample based on 280 pb⁻¹ running at the $\psi(3770)$
- Precision so far is limited by statistics
- Expect ≈ 500 pb⁻¹ in the 2005/2006 run cycle
- Additional D production when we take data at higher energies for D_s sample
- Systematic uncertainties should come down as we increase our statistical precision

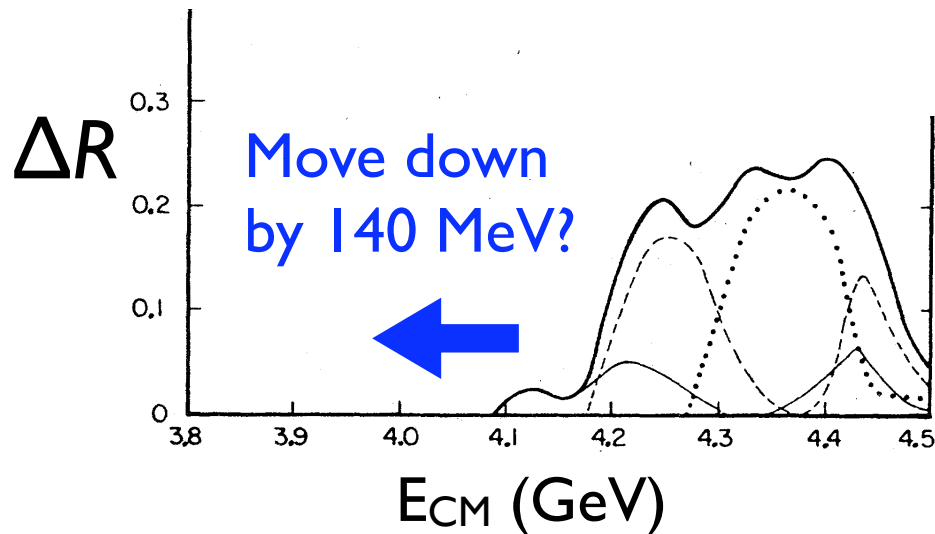
Data taking for D_s decays

e^+e^- Annihilation Cross Section



What is the cross section for producing D_s ?

Is there a resonance?



A run is set up at CLEO this August/September to answer these questions and to plan for next year.

Glueballs revisited

The final year of CLEO-c (2007/2008) was first proposed for running at the J/ψ , for $J/\psi \rightarrow \gamma + \text{glueball}$.

However the interpretation of the scalar mesons is now murky, and the evidence for the tensor glueball has gone.

What are the most definitive statements that the lattice can make about glueballs? Will mixing ever be calculable?

The CLEO-c collaboration is presently considering how to configure the third year of running in light of all new information. Any suggestions??

CLEO-c and CLEO-III References

- Improved Measurement of $B(D^+ \rightarrow \mu^+ \nu)$ and the Pseudoscalar Decay Constant f_{D^+} , CLEO-CONF 05-5
- Absolute Branching Fraction Measurements of Exclusive D^0 Semileptonic Decays, CLNS 05/1906, hep-ex/0506052
- Absolute Branching Fraction Measurements of Exclusive D^+ Semileptonic Decays, CLNS 05/1915, hep-ex/0506053
- Observation of the $h_c(1P_1)$ State of Charmonium, CLNS 05/1919, hep-ex/0505073
- First Observation of a $\Upsilon(1D)$ State, Phys.Rev.D70(2004)032001
- Observation of η'_c Production in $\gamma\gamma$ Fusion at CLEO, Phys.Rev.Lett. 92(2004)142001
- Photon transitions in $\psi(2S)$ Decays to $\chi_{cJ}(1P)$ and $\eta_c(1S)$, Phys.Rev.D70(2004)112002

Conclusion

Lots of CLEO-c physics is inspired by confrontation with Lattice QCD.

Results from CLEO-c will continue to come and precision will improve.

Our collaboration looks forward to continued interactions with the community of Lattice QCD.

Thank You!!



Hamilton
2005