Recent QCD Results from CLEO-c

April, 2006 Meeting of the American Physical Society

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Luther College, Decorah, IA, for the CLEO Collaboration

Outline

1. Introduction
   - CESR and CESR-c
   - CLEO and CLEO-c
2. Physics at the Υ Resonances
   - CLEO $\Upsilon(\mathrm{nS})$ Data Sets
   - $\Upsilon(\mathrm{nS})$ Leptonic Widths and Branching Fractions
   - $\Upsilon(\mathrm{nS})$ Hadronic Transitions
3. Physics at the $\psi(3770)$ and above
   - $\mathrm{D\overline{D}}$ at $\psi(3770)$
   - A Preview: D_s Physics
   - $\psi(nS)\to\ell^+\ell^-$ in RR from $\sqrt{s} = 3773$ MeV
   - Higher Charmonia: $\psi(4040)$, $\psi(4160)$, Y(4260)

Born 148 years ago today...

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CESR/CESR-c at Cornell

- The Cornell Electron Storage Rings have been in operation at Cornell University for over 25 years
  - Initated the era of B-physics
  - Subsequently rejuvenated the study of Υ resonances
  - Most recently became CESR-c, with a focus the charm region

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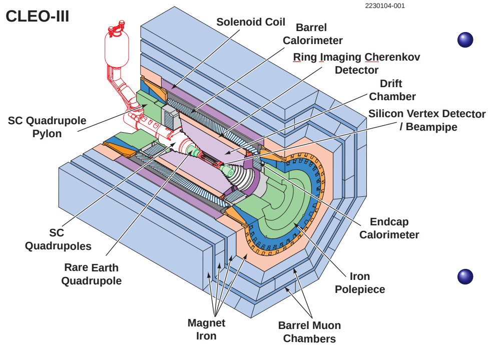
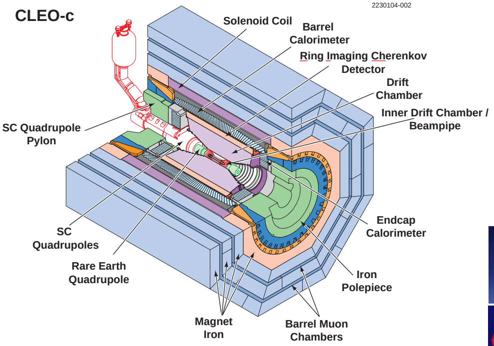
CLEOIII



- 7800-element CsI calorimeter
  - Covers 93% of 4π
  - Excellent energy resolution ($\Delta E/E \sim 4\%$ at 100 MeV)
- 47-layer drift chamber
  - Covers 93% of 4π
  - Excellent tracking resolution($\Delta p/p \sim 0.6\%$ at 1 GeV)
- PID from RICH, dE/dx

CLEO-c

- Most subdetectors identical to CLEOIII
- Silicon Vertex detector replaced with low mass vertex tracker
- Magnetic field $1.5T \rightarrow 1.0T$



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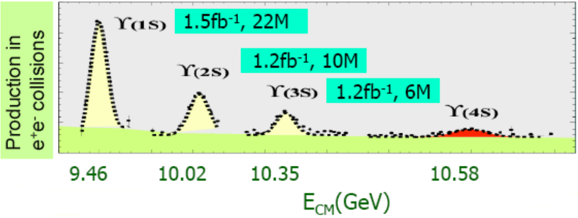
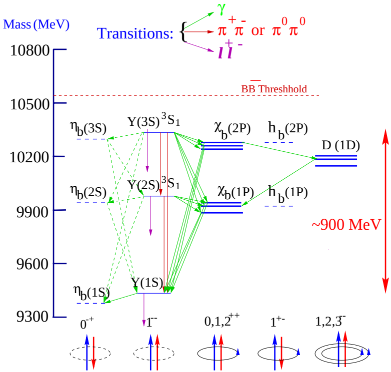
CLEO $\Upsilon(nS)$ Data Sets



- CLEO III ran on the Υ Resonances for a year between 2001 and 2002, collecting samples of Υ decays larger by factors of 10-20 compared to previous best (CLEO II)



- Among important bottomonium results that I'll not talk about are
  - Discovery of the 1D state (first CLEOIII 'confrontation' with LQCD) PRD 70, 032001 (2004)
  - Discovery of a non-$\pi\pi$ hadronic transition ($\chi_{b1,2}(2P) \to \omega\Upsilon(1S)$) PRL 92, 222002 (2004)
  - Discovery of $\pi\pi$ transitions between non-vector states PRD 73, 012003 (2006)

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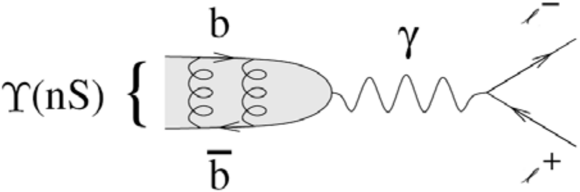
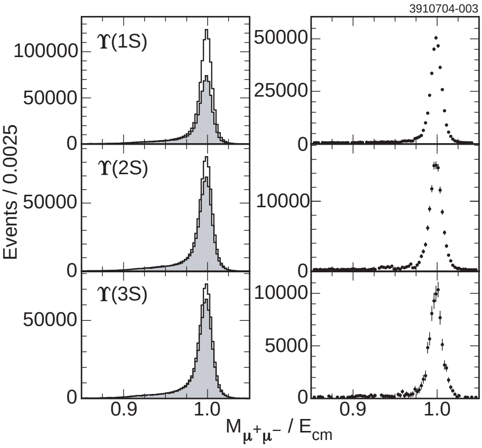


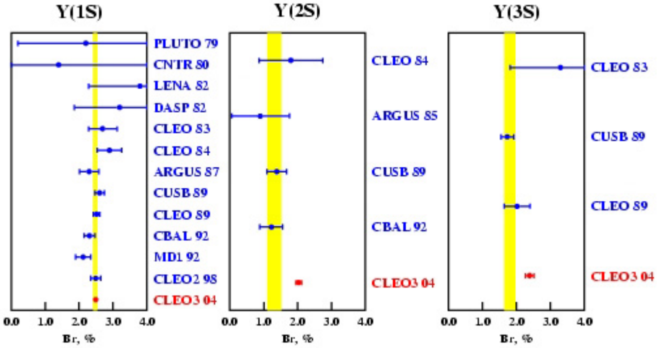
- The leptonic width of a quarkonium state is one of the basic parameters calculable in LQCD.
- At CLEO, we have recently measured anew decays of all three $\Upsilon(nS)$ states that lie below open-bottom threshold to all three lepton flavors.
- Additionally [later] we have measured e^+e^- widths for each of the 3 lowest charmonium resonances that couple to e^+e^-

$\mu^+\mu^-$ Branching Fractions

- In 2005, we published new measurements of $\mathcal{B}(\Upsilon(\mathrm{nS})\rightarrow\mu^+\mu^-)$
- Based on $1.1 - 1.2fb^{-1}$ at each $\Upsilon(\mathrm{nS})$
- Open histograms: all on-resonance data satisfying analysis cuts
- Shaded: scaled continuum data
- Points with errors: difference



$\mu^+\mu^-$ Branching Fractions



$$\mathcal{B}_{\mu\mu}(\Upsilon(1S)) = 2.49 \pm 0.02 \pm 0.07\%$$
$$\mathcal{B}_{\mu\mu}(\Upsilon(2S)) = 2.03 \pm 0.03 \pm 0.08\%$$
$$\mathcal{B}_{\mu\mu}(\Upsilon(3S)) = 2.39 \pm 0.07 \pm 0.10\%$$

PRL 94 012001 (2005)

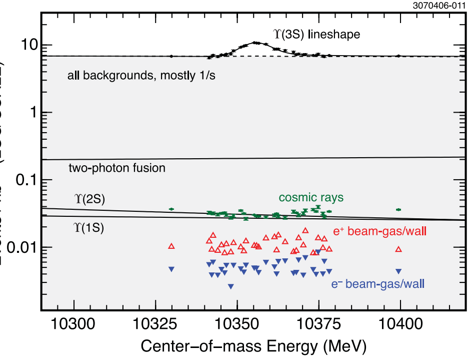
e^+e^- Widths of $\Upsilon(3S)$, $\Upsilon(2S)$ and $\Upsilon(1S)$

More recently, we have reported measurements of the Γ_{ee} for $\Upsilon(nS)$ with significant improvement in precision (c.f Relative Uncertainty on PDG 2004 Averages):

$$\Upsilon(1S) : 2.2\% \quad \Upsilon(2S) : 4.2\% \quad \Upsilon(1S) : 9.4\%$$

	Near Resonance	Below Resonance (for bkg)
11 Scans @ $\Upsilon(1S)$	0.27 fb^{-1}	0.19 fb^{-1}
6 scans @ $\Upsilon(2S)$	0.08 fb^{-1}	0.41 fb^{-1}
7 scans @ $\Upsilon(3S)$	0.22 fb^{-1}	0.14 fb^{-1}

Γ_{ee} Method

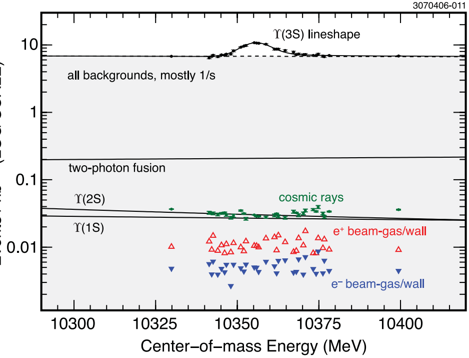


Hadronic events at 3S: dashed line is sum of bkg

- $1/s$: $\gamma^* \to \ell^+\ell^-, q\overline{q}$
- $ln(s)$: $e^+e^- \to e^+e^-\gamma\gamma$
- Cosmics/beam-gas
- $\Upsilon(2S, 1S)$*tails*

Next: fit distribution, get $\Gamma_{ee}\Gamma_{had}/\Gamma_{tot}$

Γ_{ee} Method



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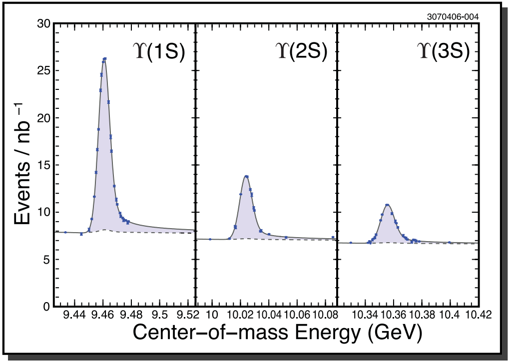


Lepton Univ.$\rightarrow \Gamma_{ee} = (\Gamma_{ee}\Gamma_{had}/\Gamma_{tot})/(1-3B_{\mu\mu})$

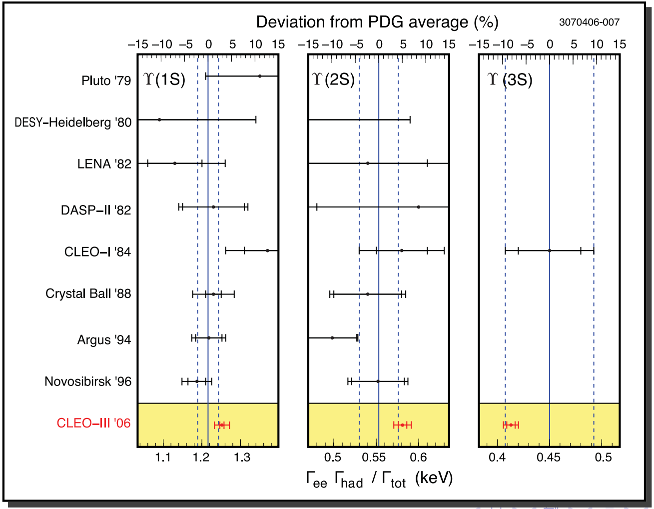
Stat err: $\Upsilon(1S, 2S, 3S)$: $0.3\%, 0.7\%, 1.0\%$.

Chief Syst. Err: $\mathcal{L}$: 1.3%, ϵ_{had} : 0.5%.

Γ_{ee} Results

		%
$\Gamma_{ee}\Gamma_{had}/\Gamma_{tot}(1S)$	$(1.252 \pm 0.005 \pm 0.019)$ keV	
$\Gamma_{ee}\Gamma_{had}/\Gamma_{tot}(2S)$	$(0.581 \pm 0.006 \pm 0.009)$ keV	
$\Gamma_{ee}\Gamma_{had}/\Gamma_{tot}(3S)$	$(0.413 \pm 0.004 \pm 0.006)$ keV	
$\Gamma_{ee}(1S)$	$(1.354 \pm 0.005 \pm 0.020)$ keV	1.5
$\Gamma_{ee}(2S)$	$(0.619 \pm 0.007 \pm 0.009)$ keV	1.9
$\Gamma_{ee}(3S)$	$(0.446 \pm 0.004 \pm 0.007)$ keV	1.8
$\Gamma_{ee}(2S)/\Gamma_{ee}(1S)$	$(0.457 \pm 0.006 \pm 0.003)$	1.5
$\Gamma_{ee}(3S)/\Gamma_{ee}(1S)$	$(0.329 \pm 0.004 \pm 0.002)$	1.3
$\Gamma_{ee}(3S)/\Gamma_{ee}(2S)$	$(0.720 \pm 0.011 \pm 0.006)$	1.7

Comparison to Previous Experimental Results

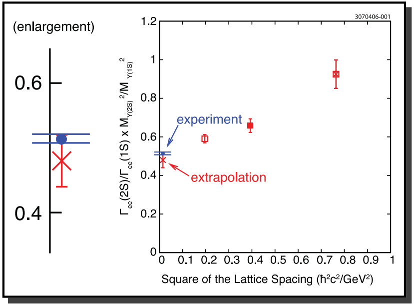


Comparison to unquenched LQCD

The best object for comparison is: $\frac{\Gamma_{ee}(\Upsilon(2S))M^2(\Upsilon(2S))}{\Gamma_{ee}(\Upsilon(1S))M^2(\Upsilon(1S))}$

CLEO-c: 0.514 ± 0.007 PRL 96, 092003 (2006).

LQCD: 0.48 ± 0.05 PRD 72, 094507 (2005).

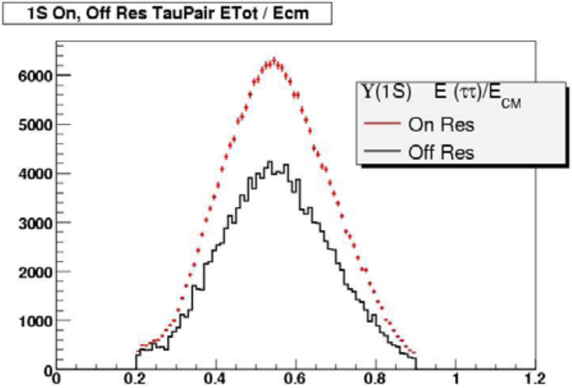


$\Upsilon(\mathrm{nS}) \to \tau\tau$

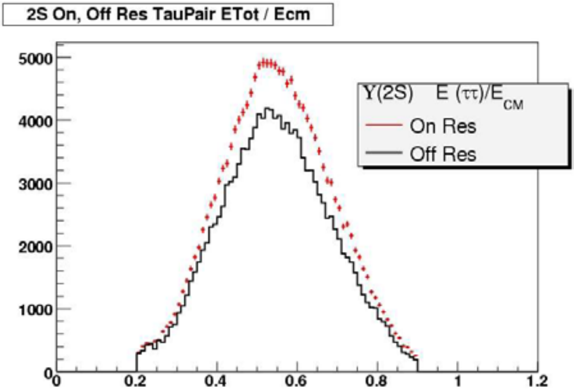
- We have recently measured $\tau\tau$ decays at all 3 lowest $\Upsilon(\mathrm{nS})$ resonances
- Previously: $\mathcal{B}(\Upsilon(1S) \to \tau\tau)$ known to 10%, $\Upsilon(2S) \to \tau\tau$ "seen", $\Upsilon(3S) \to \tau\tau$ unknown.
- Use 1-prong τ decays ($\tau \to h\nu$, $\tau \to \mu\nu\nu$), about 75%.
- Ratio to $\mu^+\mu^-$ reported:

$$\mathcal{R} \equiv \frac{\mathcal{B}(\Upsilon(\mathrm{nS}) \to \tau\tau)}{\mathcal{B}(\Upsilon(\mathrm{nS}) \to \mu^+\mu^-)}$$

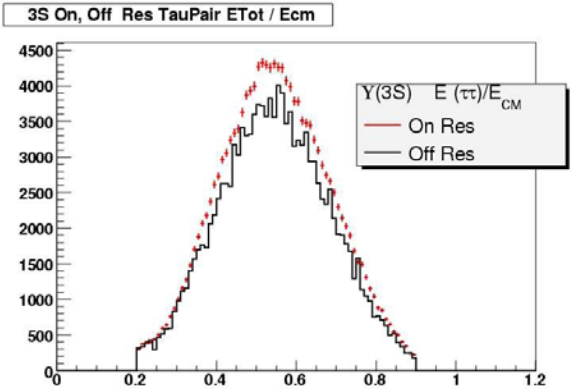
$\Upsilon(1S) \to \tau\tau$: Preliminary



$\Upsilon(2S)\to\tau\tau$: Preliminary

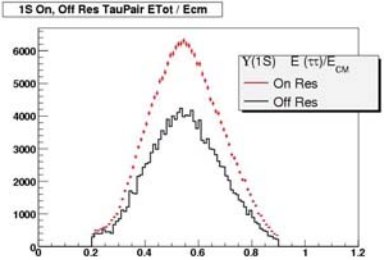


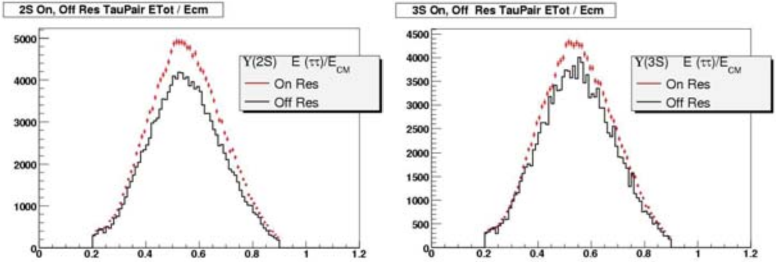
$\Upsilon(3S)\to\tau\tau$: Preliminary



$\Upsilon(nS) \to \tau\tau$: Preliminary

$\Upsilon(1S)$ Yield:	28113 ± 534
$\Upsilon(2S)$ Yield:	11082 ± 473
$\Upsilon(3S)$ Yield:	7544 ± 690



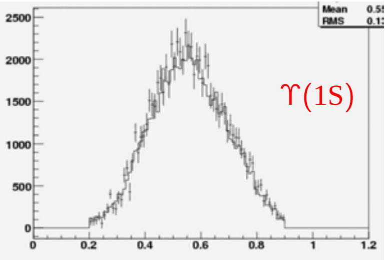


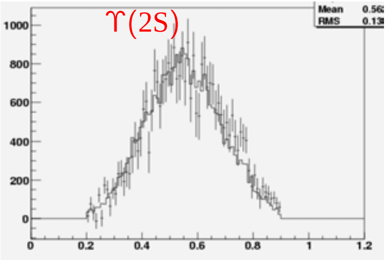
$R_{\tau\tau} \equiv (\mathcal{B}_{\tau\tau})/(\mathcal{B}_{\mu\mu})$: Preliminary

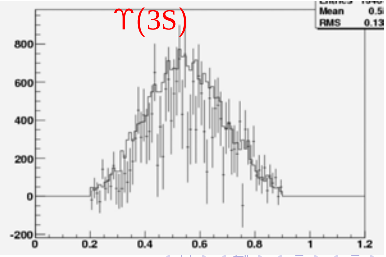
- Again: E_{vis}/E_{cm}
- Histogram: MC with $B_{\tau\tau} = B_{\mu\mu}$

$R(\Upsilon(1S))$:	$1.06 \pm 0.02 \pm 0.00 \pm 0.03$
$R(\Upsilon(2S))$:	$1.00 \pm 0.03 \pm 0.12 \pm 0.03$
$R(\Upsilon(3S))$:	$1.05 \pm 0.07 \pm 0.05 \pm 0.03$

Err: Stat, Feedthru, Other Syst.







Outline

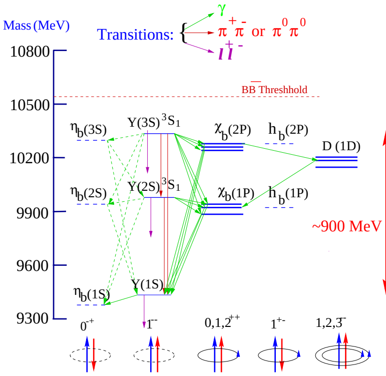
$\Upsilon(\mathrm{nS})$ Hadronic Transitions

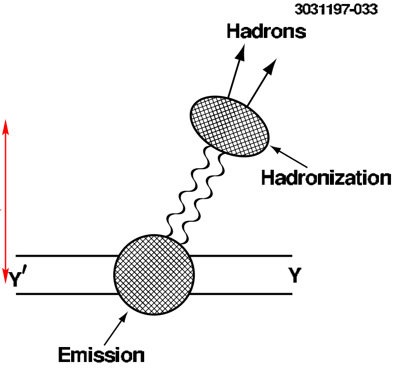
Some new developments of late in hadronic transitions among $\Upsilon(\mathrm{nS})$ states:

- CLEO: finalizing high-statistics studies of $\pi^+\pi^-$ transitions $\Upsilon(\mathrm{nS})\to\Upsilon(\mathrm{mS})\pi\pi$ Plots shown today are preliminary
- Belle: Observed $\Upsilon(4S)\to\Upsilon(1\mathrm{S})\pi^+\pi^-$
- BaBar: Observed $\Upsilon(4S)\to\Upsilon(1\mathrm{S})\pi^+\pi^-$ and $\Upsilon(4S)\to\Upsilon(2\mathrm{S})\pi^+\pi^-$

and an interesting picture emerges...

$\Upsilon(nS)$ Hadronic Transitions





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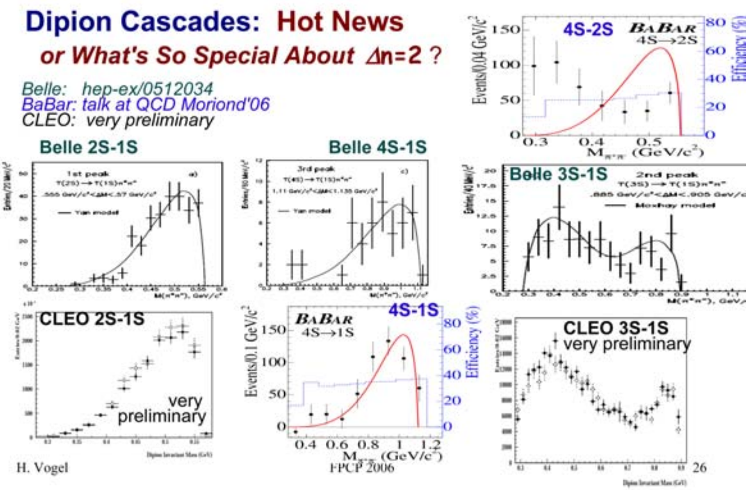

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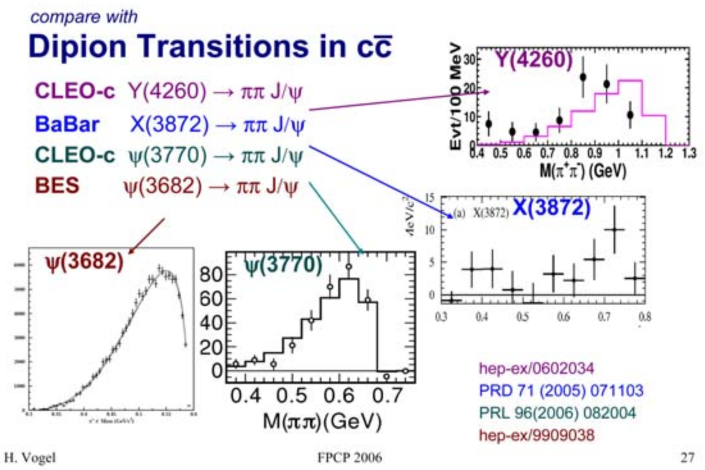


Some Additional Appetizers

More CLEO Υ Results in the pipeline :

- Final Branching Ratios for $\Upsilon(\mathrm{nS}) \rightarrow \pi^+\pi^-\Upsilon(\mathrm{mS})$, and relevant angular distributions
- Searches for h_b and η_b, $\Upsilon(\mathrm{nS}) \rightarrow \Upsilon(\mathrm{mS}) +$ other hadrons
  - Build off success of our discovery of h_c in $\psi(2S) \rightarrow h_c \pi^0 \rightarrow \gamma \pi^0 \eta_c$, in which we found

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

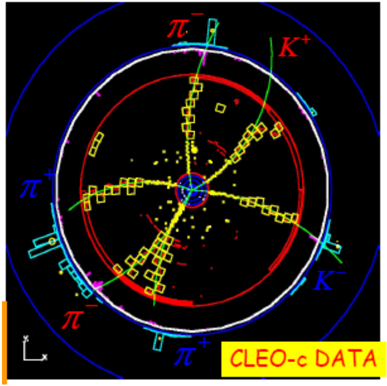
$$\Delta M_{hf} = < M(^3P_J) - M(h_c) > = +1.0 \pm 0.6 \pm 0.4 MeV$$

Future run of 30M $\psi(2S)$ will bolster the h_c results

Outline

$D\overline{D}$ at $\psi(3770)$

- Produce $D\overline{D}$, nothing else: clean laboratory for study of charm
- Can tag either both decays or only one, for measurements of absolute branching ratios, Decay constants, etc. $\sigma(D\overline{D})$, etc.
- Rough equivalence: $100 pb^{-1}$ with double tag = $500 fb^{-1}$ at $\Upsilon(4S)$ with both B's reconstructed.



Datasets at $\psi(3770)$

CLEO-c has so far taken two runs at $\psi(3770)$

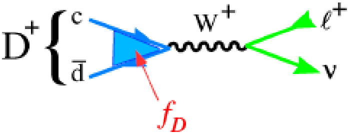
- Sept '03 - Mar '04: $\int \mathcal{L}dt = 56pb^{-1}$
- Sept '04 - Apr '05: $\int \mathcal{L}dt = 225pb^{-1}$

Results from two samples:

- $56pb^{-1}$: $360k\mathrm{D\overline{D}}$
- the full $281pb^{-1}$: $1.8M\mathrm{D\overline{D}}$

Further, over the next 2 years, expect to come to a total of at least $\int \mathcal{L}dt = 750pb^{-1}$ at $\psi(3770)$

Leptonic D Decays



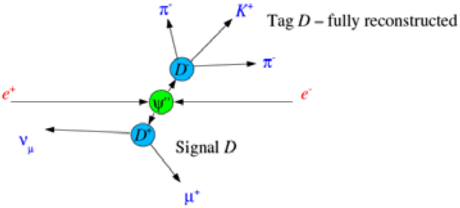
$$\Gamma(D\to\mu\nu) = \frac{G_F^2}{8\pi}|V_{cd}|^2 f_D^2 m_\ell^2 M_D^2 \left(1 - \frac{m_\ell^2}{M_D^2}\right)^2 .$$

From leptonic decays, we can extract the decay constant f_D.

- SM predicts $e\nu : \mu\nu : \tau\nu = 2.3 \times 10^{-5} : 1 : 2.65$ for D
- While $\tau^+\nu$ has $\sim$ twice the b.r., but the 2 neutrinos produced make the measurement less clean
- $e^+\nu$ is highly helicity suppressed (factor 10^5)

Best bet is $D^+\to\mu^+\nu$: prior to $\sim$ 2004, only a few events observed.

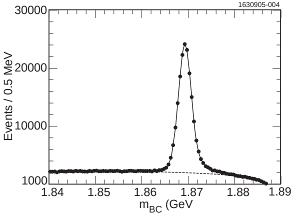
$D\to\mu\nu$ Analysis Strategy



Six Tag Modes	
$K^+\pi^-\pi^-$	$K^+\pi^-\pi^-\pi^0$
$K_S\pi^-$	$K_S\pi^-\pi^-\pi^+$
$K_S\pi^-\pi^0$	$K^+K^-\pi^-$

$\Sigma\mathcal{B} = 26.4\%,\ \epsilon = 20 - 55\%$

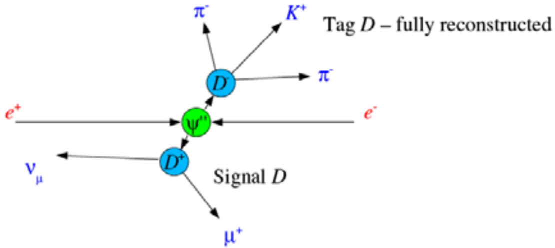
$\sim 160,000$ tags in full 281pb^{-1}



D selection via:

$$M_{BC}^2 = E_{beam}^2 - \Sigma(\vec{p}_i^{\,2})\ ;\ \Delta E = E_{beam} - \Sigma(E_i).$$

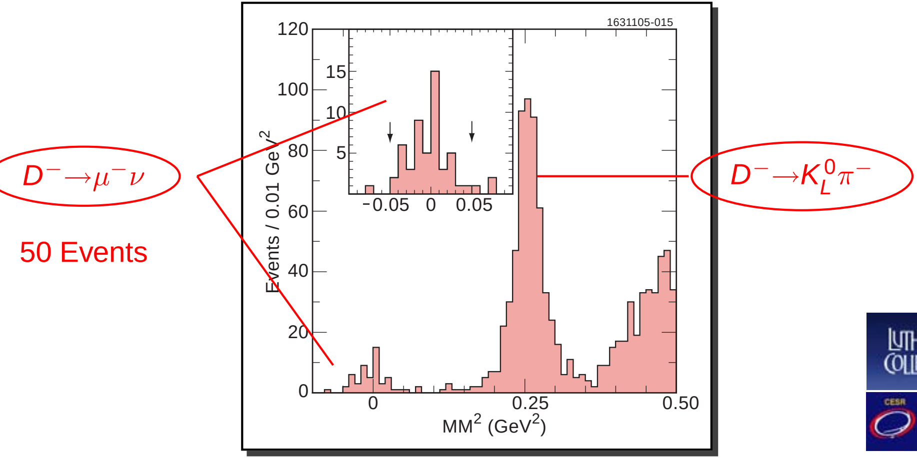
$D \rightarrow \mu\nu$ Analysis Strategy



- Detect the muon together with tagged D
- We know $E_{D^+} = E_{beam}, \vec{p}_{D^+} = -\vec{p}_{D^-}$.
- Compute the missing mass squared $MM^2_{miss} = (E_{beam} - E_\mu)^2 - (\vec{p}_{D^-} + \vec{p}_\mu)^2$
- at $MM^2_{miss} = 0$ we have our signal

$D \to \mu\nu$ in CLEO-c Data

From the CLEO-c $281 pb^{-1}$ set, we find:



$\mathcal{B}(D\to\mu\nu)$ and f_D

Backgrounds evaluated: $D^+\to\pi^+\pi^0(1.4)$,$K_L\pi^+(0.33)$ and $\tau^+\nu_\tau(1.08)$ for a total of 2.81 events.
With our 50 events in the signal region, we then obtain

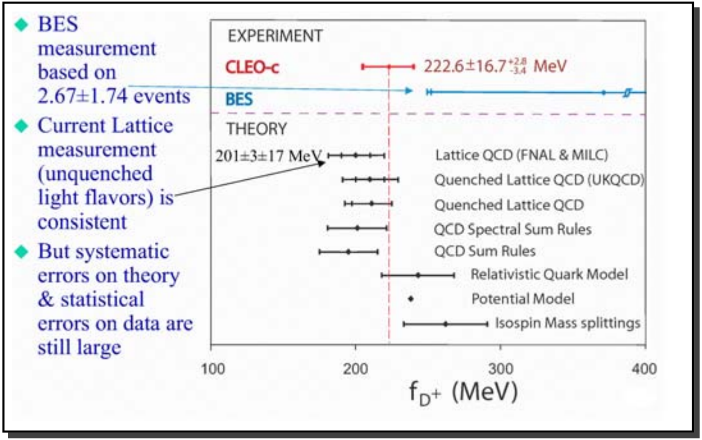
$$\mathcal{B}(D^+\to\mu^+\nu) = (4.40\pm 0.66^{+0.09}_{-0.12})\times 10^{-4}.$$

Couple this with $\tau(D^+) = 1.040\pm 0.007 ps$ and $|V_{cd}| = 0.2238\pm 0.0029$ (PDG) and we obtain:

$$f_D = 222.6\pm 16.7^{+2.8}_{-3.4}\ \text{MeV}.$$

CLEO-c: PRL 95 251801 (2005)

Comparison to Theoretical Predictions

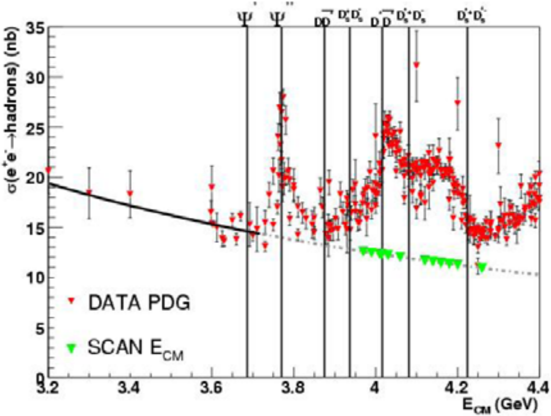


Lattice: PRL 95 122002 (2005)

Outline

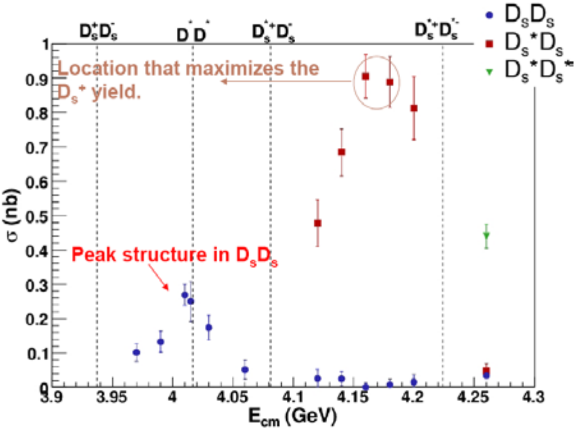
D_S at CLEO-c

- f_{D_S} also calculable: $f_{D_S} = 249 \pm 3 \pm 16$ MeV. (1.1-1.3 usual ratio to f_D)
- Best measurement thus far by Babar on $230fb^{-1}$: $f_{D_S} = 279 \pm 17 \pm 6 \pm 19$ MeV.
- Ratio to our f_D : 1.25
- The last uncertainty is due to the absolute branching ratio scale (i.e. $D_S \to \phi\pi$)
- We are looking to obtain both precise D_S BRs, and f_{D_S} in a similar manner to our measurements for D mesons



Scan of 12 points, 60pb^{-1} to obtain best running point for studies of D_s BR and f_{D_s}

D_S Cross Sections Preliminary



For production of D_S, we have chosen to run at 4170 MeV

D_S Branching Fractions Preliminary

Mode	$\mathcal{B}$ (%) (CLEO-c)	$\mathcal{B}$ (%) PDG
$K_S K^+$	$1.28^{+0.13}_{-0.12} \pm 0.02$	1.80±0.55
$K^+K^-\pi^+$	$4.54^{+0.44}_{-0.42} \pm 0.09$	4.3±1.2
$K^+K^-\pi^+\pi^0$	$4.83^{+0.49}_{-0.46} \pm 0.49$	-
$\pi^+\pi^+\pi^-$	$1.02^{+0.11}_{-0.10} \pm 0.06$	1.00±0.28

- With only a first shot of 76pb^{-1}: already world best.
- We are currently wrapping up a full $200pb^{-1}$ sample
- Ultimately we will have no less than $750pb^{-1}$ total.

Hence: much more precise BR's for these and other modes, and a few percent measurement of f_{D_S} are expected.

Outline

non-$D\bar{D}$ decays of $\psi(3770)$

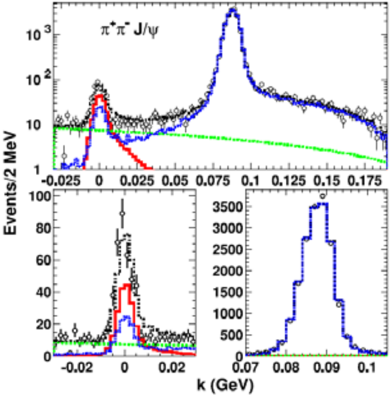
CLEO-c has made a number of other important measurements of non-$D\bar{D}$ decays of $\psi(3770)$

- $\sigma_{had}(\psi(3770))$ (c.f.$\sigma(\psi(3770)\to D\bar{D})$) and $\Gamma_{ee}(\psi(3770))$
  - By measuring σ_{tot}, and taking M and Γ_{tot} from PDG, obtain $\Gamma_{e^+e^-}(\psi(3770)) = 0.204 \pm 0.003^{+0.041}_{-0.027} keV$.
- $\mathcal{B}(\psi(3770)\to\gamma\chi_{cJ}(1P))$: argues for $\psi(3770)$ as dominantly ${}^3D_1$
- several others

In addition, while studying non-$D\bar{D}$ decays of $\psi(3770)$, investigated

$\Gamma_{ee}(J/\psi), \Gamma_{tot}(J/\psi), \Gamma_{ee}(\psi(2S))/\Gamma_{ee}(J/\psi)$

While running at $\psi(3770)$, we have been able to measure the dielectron widths of $\psi(2S)$ and J/ψ through radiative return, to excellent precision:



$$\Gamma_{e^+e^-}(\psi(2S)) = 2.54 \pm 0.03 \pm 0.11 keV$$

$\Gamma_{ee}(J/\psi), \Gamma_{tot}(J/\psi), \Gamma_{ee}(\psi(2S))/\Gamma_{ee}(J/\psi)$

Select $\mu^+\mu^-(\gamma)$ events with $M(\mu^+\mu^-) = M(J/\psi)$. Cross section that results is $\propto B_{\mu^+\mu^-}\Gamma_{ee}$

$$\mathcal{B}(J/\psi\to\mu^+\mu^-) \times \Gamma_{e^+e^-}(J/\psi) = 0.3384 \pm 0.0058 \pm 0.0071 \text{ keV}$$

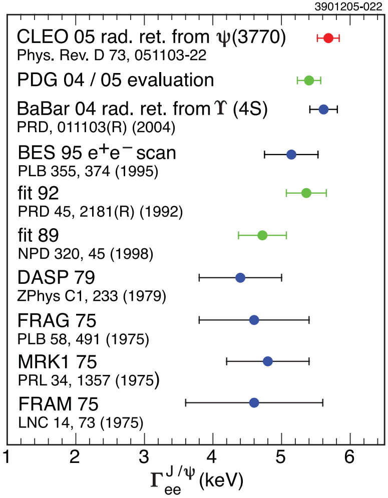
Divide resulting cross section by $B(J/\psi\to\mu^+\mu^-)$:

$$\Gamma_{e^+e^-}(J/\psi) = 5.68 \pm 0.11 \pm 0.13 \text{ keV.}$$

Assume lepton universality, and get $\Gamma_{tot}(J/\psi)$

$$\Gamma_{tot}(J/\psi) = 95.5 \pm 2.4 \pm 2.4 \text{ keV}$$

For comparison: J/ψ e^+e^- width measurements



$\Gamma_{ee}(J/\psi), \Gamma_{tot}(J/\psi), \Gamma_{ee}(\psi(2S))/\Gamma_{ee}(J/\psi)$

Taking the 2S to 1S ratio, we find:

$$\frac{\Gamma_{e^+e^-}(\psi(2S))}{\Gamma_{e^+e^-}(J/\psi)} = 0.45 \pm 0.01 \pm 0.02$$

and again making the ratio most useful for LQCD:

$\mathcal{R}(c\overline{c}) \equiv \frac{\Gamma_{ee}(2S)M^2(2S)}{\Gamma_{ee}(1S)M^2(1S)}$, we find $\mathcal{R} = 0.64 \pm 0.03$

Comparing to previous world average:

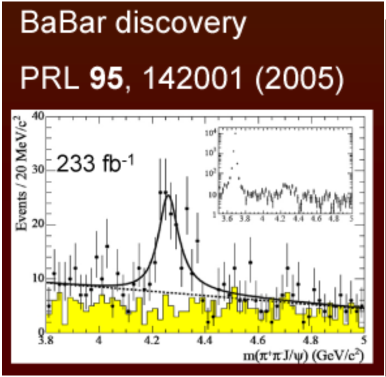
$\mathcal{B}_{\mu^+\mu^-}(J/\psi) \times \Gamma_{e^+e^-}(J/\psi)$	3.0%	3.2%
$\Gamma_{e^+e^-}(J/\psi)$	3.0%	3.1%
$\Gamma_{tot}(J/\psi)$	3.4%	3.5%
$\Gamma_{e^+e^-}(\psi(2S))/\Gamma_{e^+e^-}(J/\psi)$	4.9%	6.5%

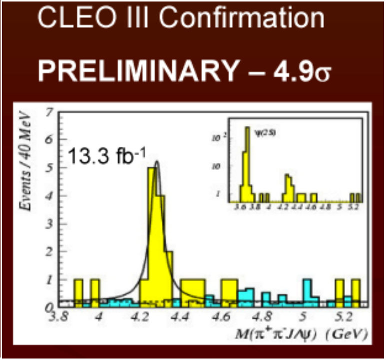
PRD 73, 051103(R), (2006). PRL 96, 082004, (2006).

Outline

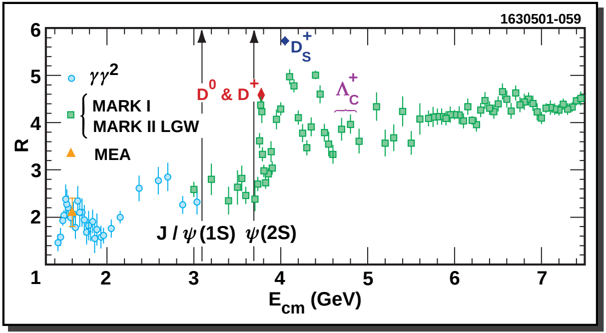
1. Introduction
   - CESR and CESR-c
   - CLEO and CLEO-c
2. Physics at the Υ Resonances
   - CLEO $\Upsilon(\mathrm{nS})$ Data Sets
   - $\Upsilon(\mathrm{nS})$ Leptonic Widths and Branching Fractions
   - $\Upsilon(\mathrm{nS})$ Hadronic Transitions
3. Physics at the $\psi(3770)$ and above
   - $D\overline{D}$ at $\psi(3770)$
   - A Preview: D_s Physics
   - $\psi(nS)\rightarrow\ell^+\ell^-$ in RR from $\sqrt{s} = 3773$ MeV
   - Higher Charmonia: $\psi(4040)$, $\psi(4160)$, Y(4260)

Higher Charmonia: $\psi(4040)$, $\psi(4160)$, Y(4260)





Higher Charmonia: $\psi(4040)$, $\psi(4160)$, Y(4260)

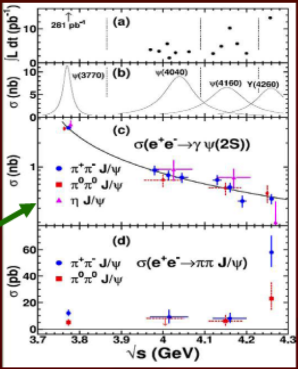


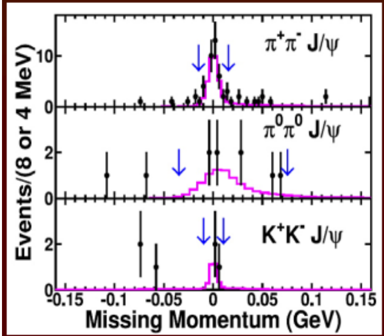
$Y(4260)$ is at a minimum in R

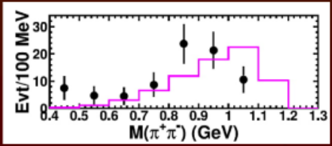
	$\int L dt$ (pb^{-1})	E_{CM} (MeV)
ψ(4040)	20.7	3970-4060
ψ(4160)	26.3	4120-4200
ψ(4260)	13.2	4260

Search for 16 final states with J/ψ, $\psi(2S)$, χ_{cJ}, ϕ

Use $e^+e^-\to\gamma\psi(2S)$ to verify efficiency, background, luminosity.







- $Y(4260) \to \pi^+\pi^- J/\psi$ confirmed @11σ
- First observation of $Y(4260) \to \pi^0\pi^0 J/\psi$ (5.1σ) and first evidence for $Y(4260) \to K^+K^- J/\psi$ (3.7σ), plus in-progress open-charm studies should narrow the explanations.

(hep-ex/0602034, accepted by PRL)

Summary

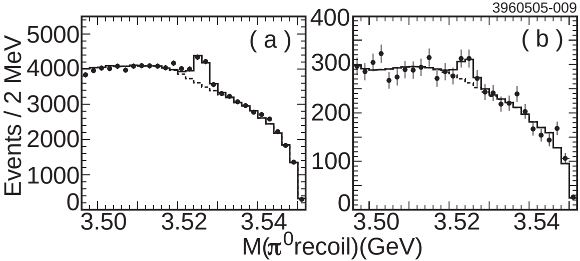
- Over the course of the past year or so, CLEO has produced a wide array of results that provide important checks/tuning for (L)QCD
  - Dilepton widths/branching ratios for many onia
  - Leptonic width for D (hence, f_D)
  - A host of other first observations or precise confirmations
- CLEO will continue to offer challenges to LQCD with
  - Continued searches for $b\bar{b}$ singlets
  - a total of 750 pb^{-1} $D\bar{D}$: improve f_D (281pb^{-1})
  - a total of 750 pb^{-1} $D_S\bar{D}_S$: improve $BR(D_S)$, f_{D_S} (78pb^{-1})
  - 30M $\psi(2S)$ lots of charmonium spectroscopy, incl. h_c, η_c (3M$\psi(2S)$)

And an invitation: Session L12 (3:15, Cumberland F) - Many CLEO-c D results including semileptonic decays and absolute branching fractions

Cited CLEO publications

Observation of h_c

PRL 95, 102003 (2005)



D^- single tags (281 pb^{-1}): $158,354 \pm 496$

$D^-\to K^+\pi^-\pi^-$

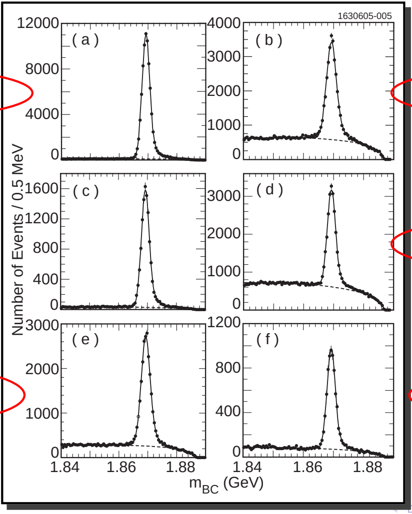
$D^-\to K^+\pi^-\pi^-\pi^0$

$D^-\to K_S\pi^-$

$D^-\to K_S\pi^-\pi^-\pi^+$

$D^-\to K_S\pi^-\pi^0$

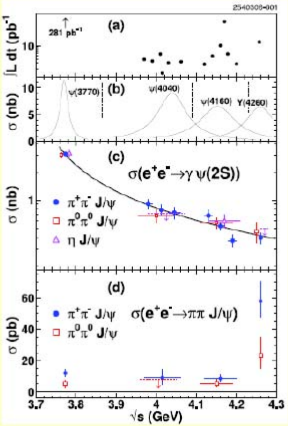
$D^-\to K^+K^-\pi^-$



The Real $\mathcal{B}(D_S \to \phi\pi^+)$

- The FOCUS Dalitz plot analysis has the $\phi\pi^+$ fraction of $K^+K^-\pi^+$ =0.45±0.01
- Dividing by the CLEO number for $\mathcal{B}(D_S \to K^+K^-\pi^+)$ by $\mathcal{B}(\phi \to K^+K^-)$=.491, gives $\mathcal{B}(D_S \to \phi\pi^+)$=(4.16±0.41)%
- This is the branching ratio that is most appropriate to compare with theoretical calculations

Y(4260) in CLEO-c data

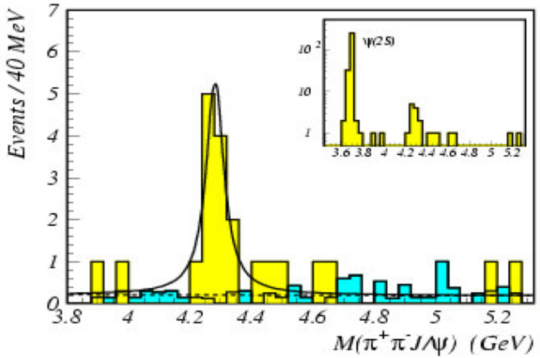


CLEO Data:
D_s scan + 4.17GeV + 3.77GeV

Channels studied:
15 with charmonium + $\phi\pi\pi$

Cross-check: $e^+e^- \to \gamma\psi(2S)$ ✓

Signals at 4.26GeV: $\pi^+\pi^- J/\psi$ (11σ), $\pi^0\pi^0 J/\psi$ (5.1σ), $K^+K^- J/\psi$ (3.7σ)



clean 4.9σ signal

seen in ISR from 13.3fb$^-1$ at $\Upsilon(1,2,3,4S)$

$\sigma_{had}(\psi(3770))$ and $\Gamma_{ee}(\psi(3770))$

- Use double-D tags, simultaneously fitting for 6 charged and 3 neutral decays of $D^\pm$ and $(D^0/\overline{D}^0)$:
- Effectively a count D's to arrive at a $\mathrm{D}\overline{\mathrm{D}}$ cross section for $\psi(3770)$

$$\begin{array}{ll} \sigma(e^+e^- \to \mathrm{D}\overline{\mathrm{D}}) & (6.39 \pm 0.10^{+0.17}_{-0.08})\mathrm{nb} \\ \sigma(e^+e^- \to D^0\overline{D}^0) & (3.60 \pm 0.07^{+0.07}_{-0.05})\mathrm{nb} \\ \sigma(e^+e^- \to D^+D^-) & (2.79 \pm 0.07^{+0.10}_{-0.04})\mathrm{nb} \end{array}$$

Charged to Neutral Ratio:

$$\frac{\sigma(e^+e^- \to D^+D^-)}{\sigma(e^+e^- \to D^0\overline{D}^0)} = 0.776 \pm 0.024^{+0.014}_{-0.006}.$$

PRL 95, 121801 (2005).

$\sigma_{had}(\psi(3770))$ and $\Gamma_{ee}(\psi(3770))$

We have also studied the number of hadronic events, N_{had} in these data (selection essentially counts $N_{tr} \geq 3$ and $E_{vis}/\sqrt{s} > 0.3$.
With continuum subtraction from data taken below $\psi(2S)$ and subtraction of known RR to $\psi(2S)$ and J/ψ, we find:

$$\sigma_{had}(\psi(3770)) = 6.38 \pm 0.08^{+0.41}_{-0.30}\ nb.$$

We then have

$$\sigma_{nonD\overline{D}} = \sigma_{had}(\psi(3770)) - \sigma_{D\overline{D}}(\psi(3770)) = -0.01 \pm 0.08^{+0.41}_{-0.30}\ nb.$$

The observed non-$D\overline{D}$ decays are consistent with this small difference. Then, taking the observed total cross section, plus $M(\psi(3770))$ and $\Gamma(\psi(3770)$ from PDG, we obtain:

$$\Gamma_{e^+e^-}(\psi(3770)) = 0.204 \pm 0.0.003^{+0.041}_{-0.027} keV.$$

Dilepton Decay Summary from CLEOIII/-c

CLEO has ammassed a large number of measurements of the important dilepton decays of both bottomonium and charmonium

Quantity	CLEO Result	Previous World Avg
$\Gamma_{e^+e^-}(\Upsilon(3S))$		
$\Gamma_{e^+e^-}(\Upsilon(1S))$		
$\Gamma_{e^+e^-}(\Upsilon(1S))$		
$\mathcal{B}(\Upsilon(3S)\to\mu^+\mu^-)$		
$\mathcal{B}(\Upsilon(2S)\to\mu^+\mu^-)$		
$\mathcal{B}(\Upsilon(1S)\to\mu^+\mu^-)$		
$\Gamma_{\tau\tau}/\Gamma_{\mu^+\mu^-}(\Upsilon(3S))$		
$\Gamma_{\tau\tau}/\Gamma_{\mu^+\mu^-}(\Upsilon(2S))$		
$\Gamma_{\tau\tau}/\Gamma_{\mu^+\mu^-}(\Upsilon(1S))$		
$\Gamma_{e^+e^-}(\psi(3770)$		