

Heavy Quarkonia Spectroscopy and Decay

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Physics in Collision 2003



1 Introduction

1a What are Heavy Onia

1b Theory

1c Experimental Data

2 Spectroscopy

2a Transition options

2b Υ pionic transitions

2c Rare transitions

2d Searches

3 Decays

3a Scans

3b Radiative decays

3c 14% puzzle

4 What next?

Onia

- Strongly bound $q\bar{q}$ states
- Non-relativistic QM applicable (Appelquist, Politzer)
 - QCD analog to positronium
 - Provide insight into QCD
- Low Q^2 , non-perturbative



System	$(v/c)^2$	Ground Triplet State			Forces				
		1^3S_1			Binding		Decay		
		Name	$\Gamma(\text{MeV})$	$m(\text{GeV})$	EM	strong	EM	strong	weak
Positronium									
e^+e^-	~ 0.01		5×10^{-15}		✓		✓		
Quarkonium									
$u\bar{u}, d\bar{d}$	~ 1.0	ρ	150	0.77		✓		✓	
$s\bar{s}$	~ 0.8	ϕ	4.4	1.02		✓		✓	
$c\bar{c}$	~ 0.25	ψ	0.09	3.1		✓	✓	✓	
$b\bar{b}$	~ 0.08	Υ	0.05	9.46		✓	✓	✓	
$t\bar{t}$	< 0.01		3000			✓			✓

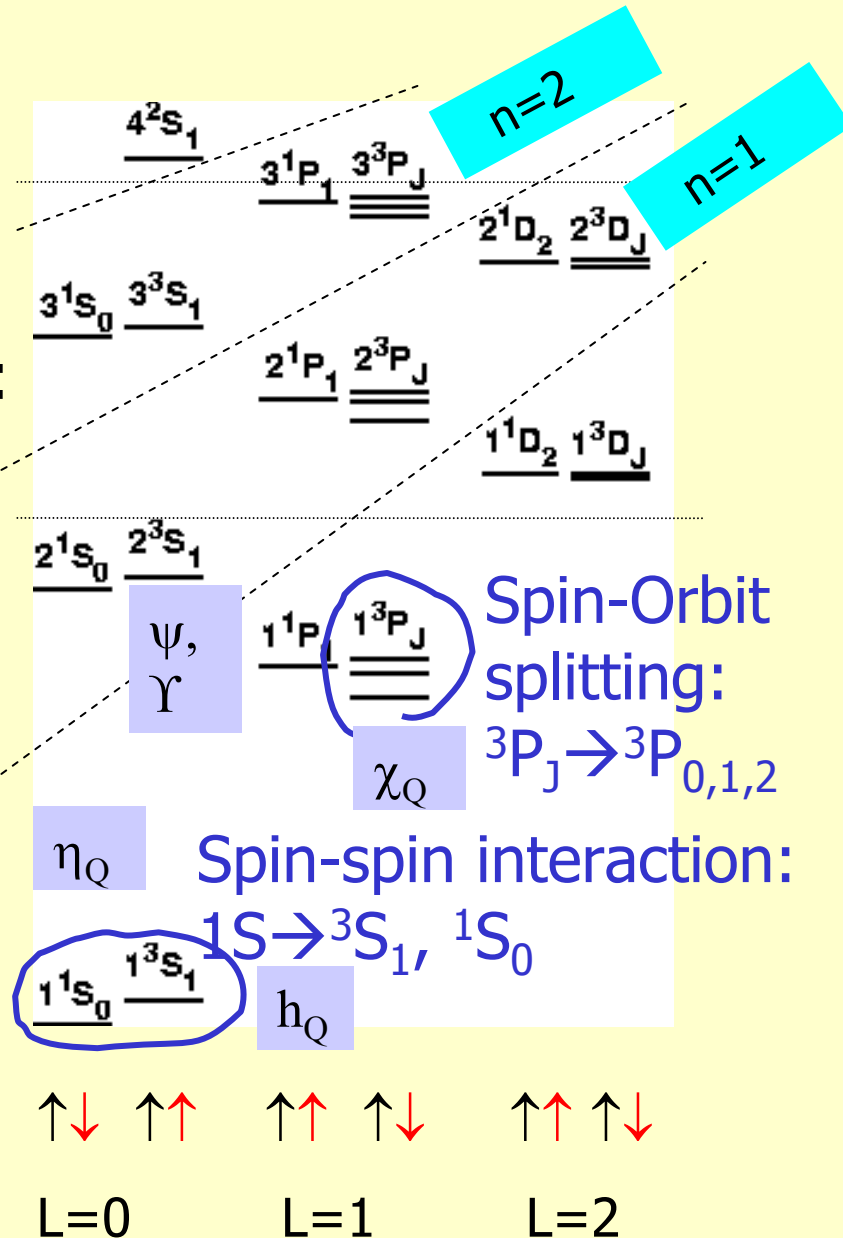
Onia states

- ? Masses
- ? Widths
- ? Production and decay dynamics

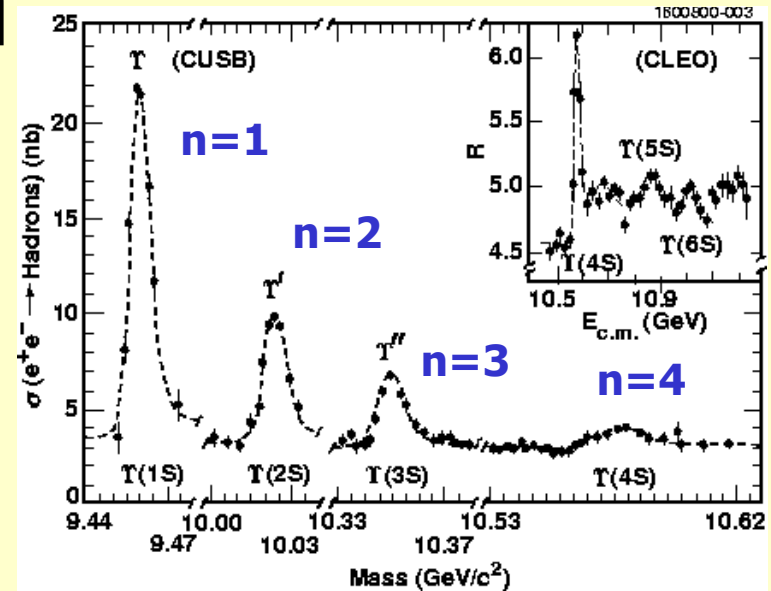
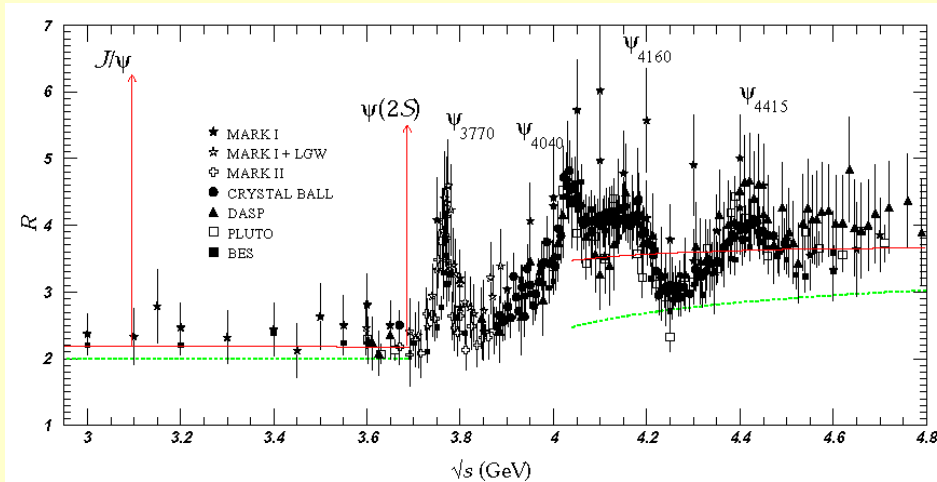
$b\bar{b}$: 560 MeV
 $c\bar{c}$: 589 MeV
 e^+e^- : 5×10^{-6} MeV

Partly discovery, partly precision measurements

Notation:
 $n^{2S+1}L_J$
 $\vec{J} = \vec{L} + \vec{S}$



Producing quarkonia



- **e^+e^- colliders, $e^+e^- \rightarrow \gamma^* \rightarrow qq$:**
can only directly produce states coupling to γ^* ,
i.e. n^3S_1 ($J/\psi, \Upsilon$) with a tiny admixture of n^3D_{1-}
- **two photon collisions:** $J=0,2$ ($\eta_{[b,c]}, \chi_{[b,c][0,2]}$)
- **hadron colliders** can do any energy, but not as clean
- **transition** from higher up, e.g. $\psi(2S) \rightarrow \gamma \chi_{c0}$

Potential Models

- Hydrogen: Coulomb, $V(r) = -\alpha_{em}/r$

Short distance, 1g exchange long distance

- Heavy Onia: $V(r) = -\frac{4}{3} \alpha_s/r + kr$

Color factor

Strong coupling
between q and g

Energy density
per distance
between q and
 \bar{q} , $\sim 1\text{GeV}/\text{fm}$

- Potential well much deeper!
- Cf positronium: measurement of energy levels, spacing and decay rates can be used to fine-tune the parameters of QED – here: QCD.

The rôle of lattice QCD

- The only complete definition of QCD, both perturbative and non-perturbative
- Made possible through effective field theories for heavy quarks (non-relativistic QCD, HQET)
- ❖ Recent breakthrough in lattice gauge theory: unquenched calculations became affordable
- Charmonium and bottomonium spectra test LQCD's ability to **calculate** strong phenomena, relevant to many aspects of heavy flavour physics (e.g. $B\bar{B}$ mixing)
- Need experimental results at the % level

Recent Progress in LQCD

Parameters:

Tune

α_S , $m_u = m_d$, m_S ,

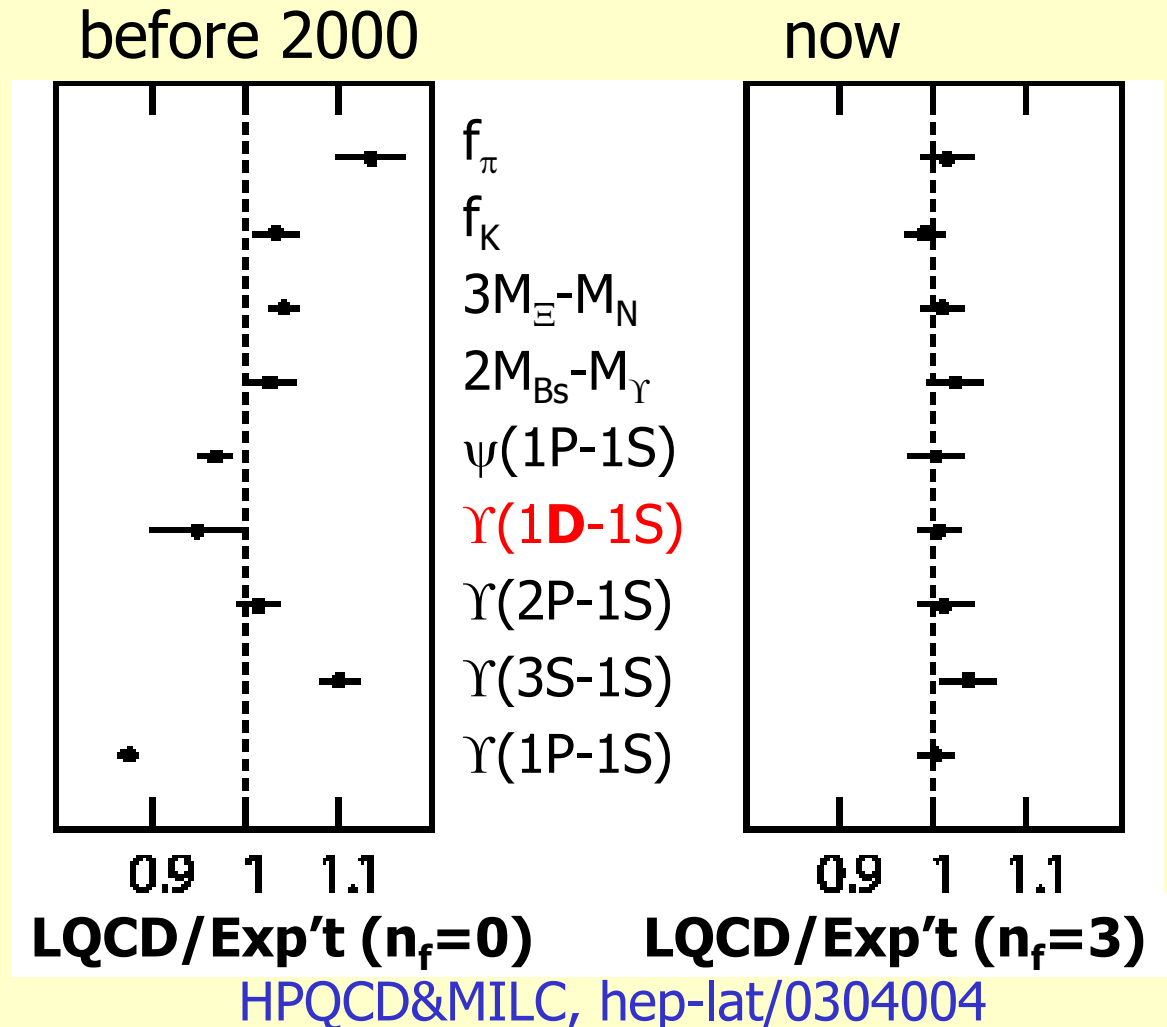
m_C , and m_b

on

m_π , m_K , m_{D_S} , m_Υ ,

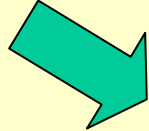
and $\Delta E_\Upsilon(2S-1S)$

New level of
precision achieved



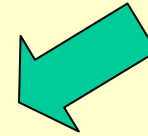
Why Investigate Heavy Quarkonia

Simplest strongly interacting systems

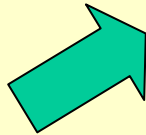


Excellent place to study an important region of the Standard Model

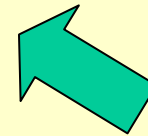
Fairly non-relativistic



Gain insight to underlying interaction, QCD



More convenient to handle than glueballs

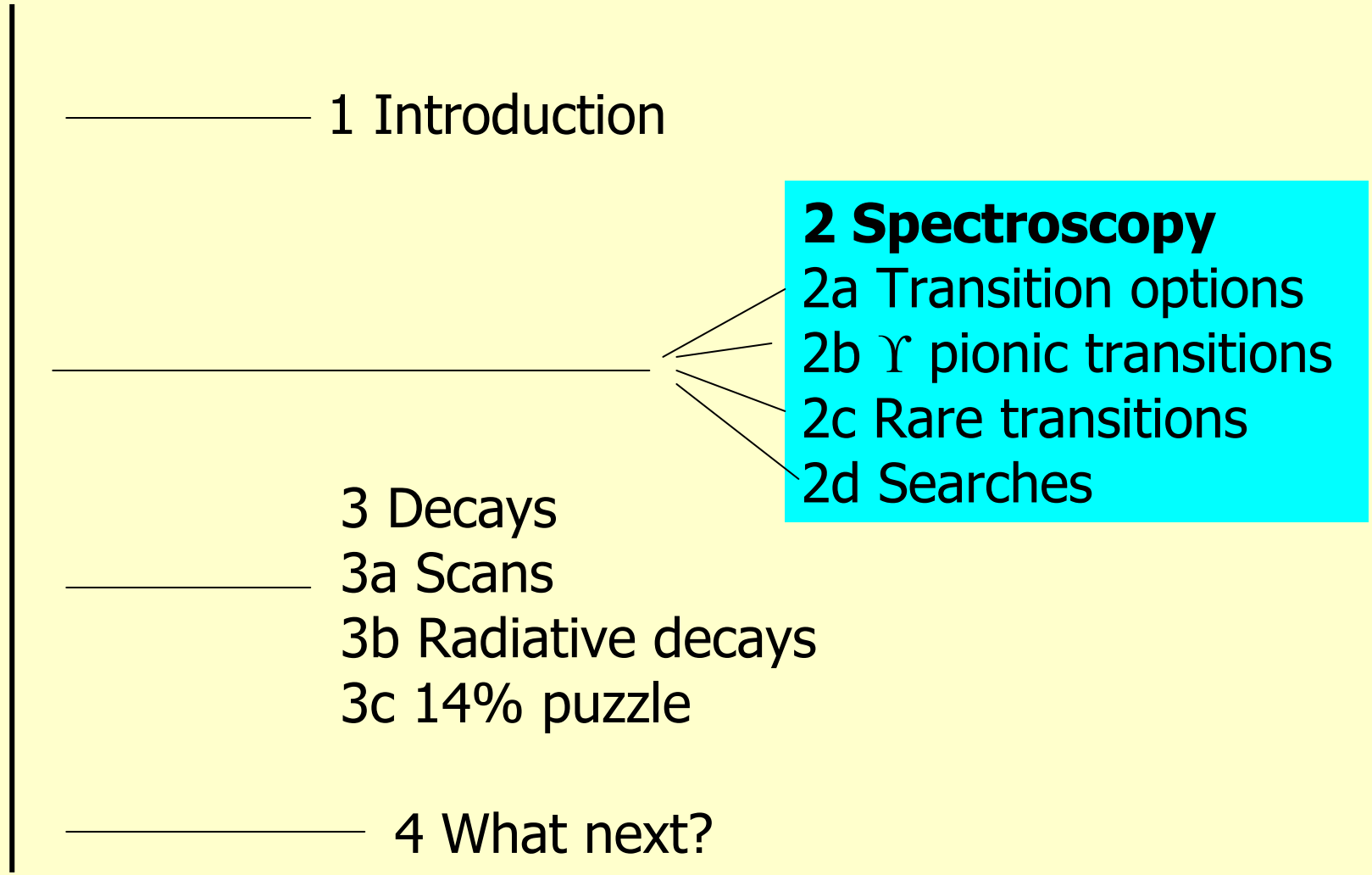


Data

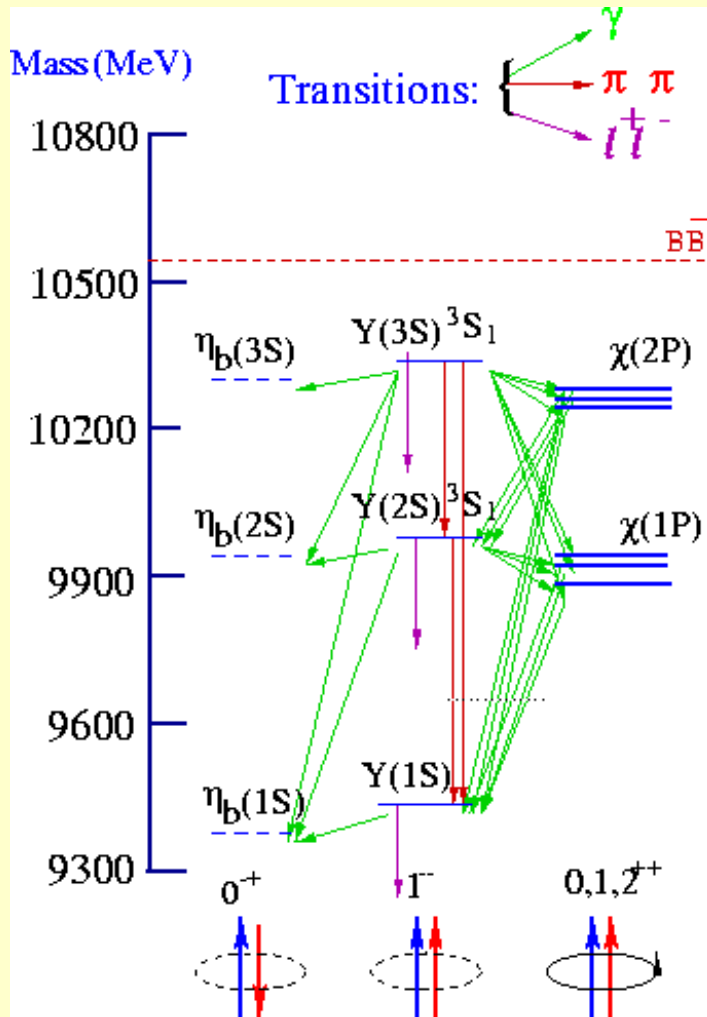
Modern Datasets

- Smaller data samples from MarkI,II,III, DM2, CLEOIII (ψ')
- Cross section falls as n increases
- Both CLEO and BES have additional data samples for special purposes

E_{cm} (GeV)	Physics	Datataking completed	#events
3.10	J/ψ	1990's	8M BES
		2001	58M BESII
3.69	$\psi(2S)$	1990's	4M BES
		2002	14M BESII
9.46	$\Upsilon(1S)$	1990's	2M CleoII
		2003	20M CleoIII
10.02	$\Upsilon(2S)$	1990's	0.5M CleoII
		2003	10M CleoIII
10.36	$\Upsilon(3S)$	1990's	0.5M CleoII
		2003	5M CleoIII
(10.58)	($\Upsilon(4S)$)	(2002)	



Transition options



- Hadronic:

- ▶ $\pi^0, \eta, \omega, \pi^+\pi^-$ - no Ks; splitting too small

- Electromagnetic (photon; $\Delta S=0$)

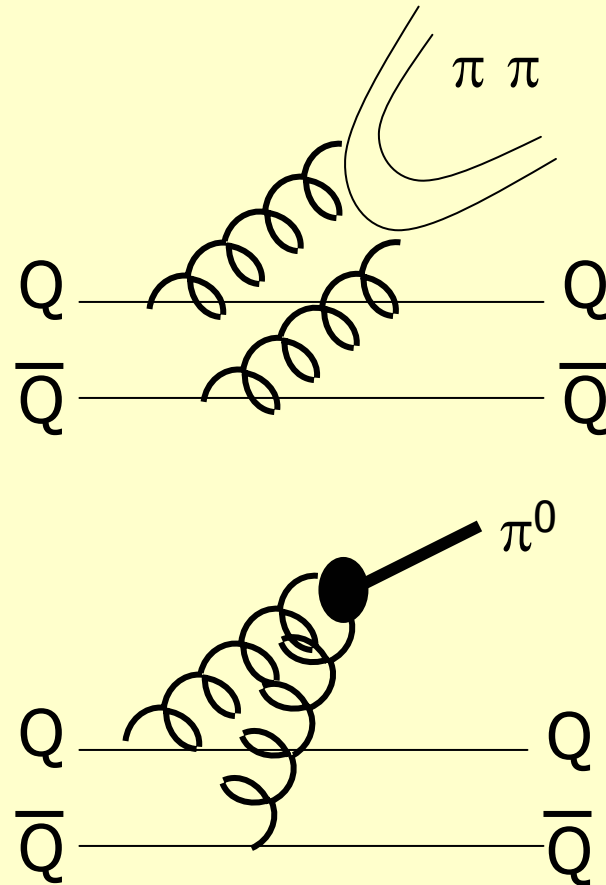
- ▶ E1: $\Delta L=1$

- ▶ M1: $\Delta L=0$

Hadronic Transitions

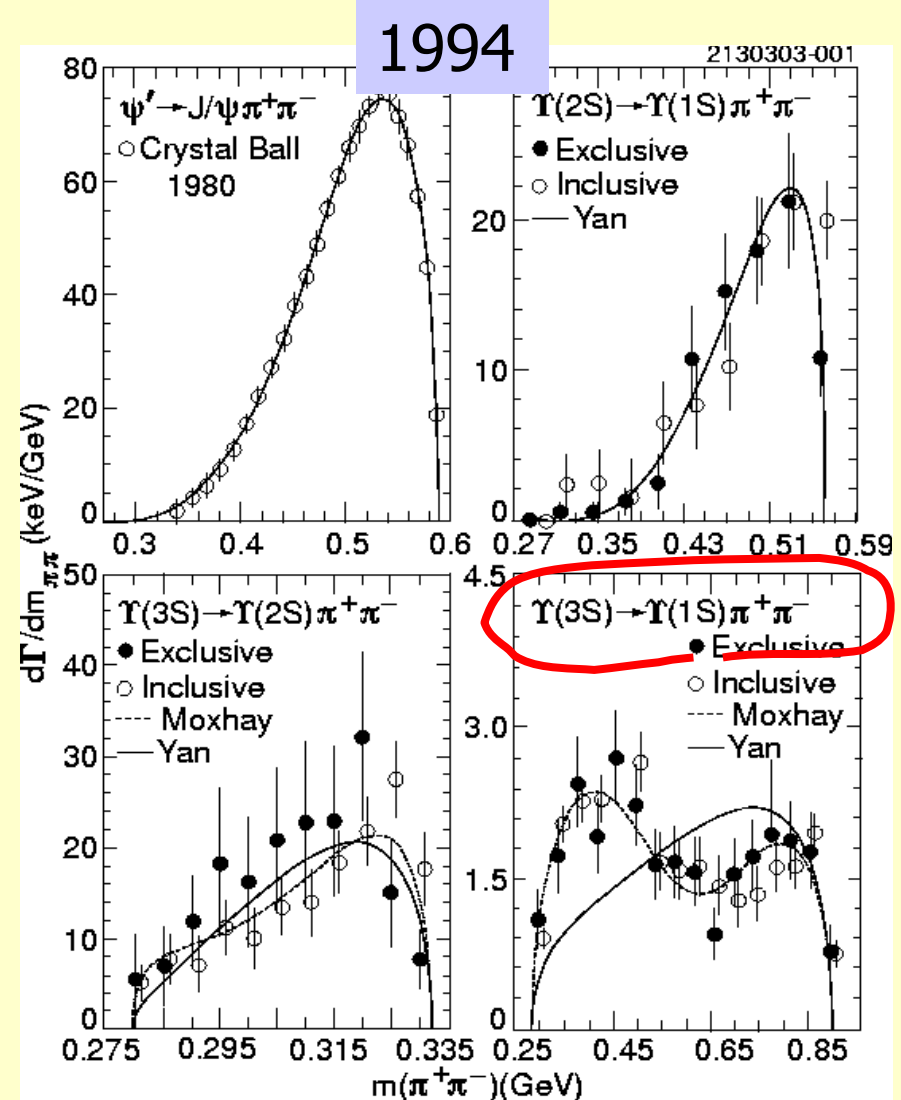
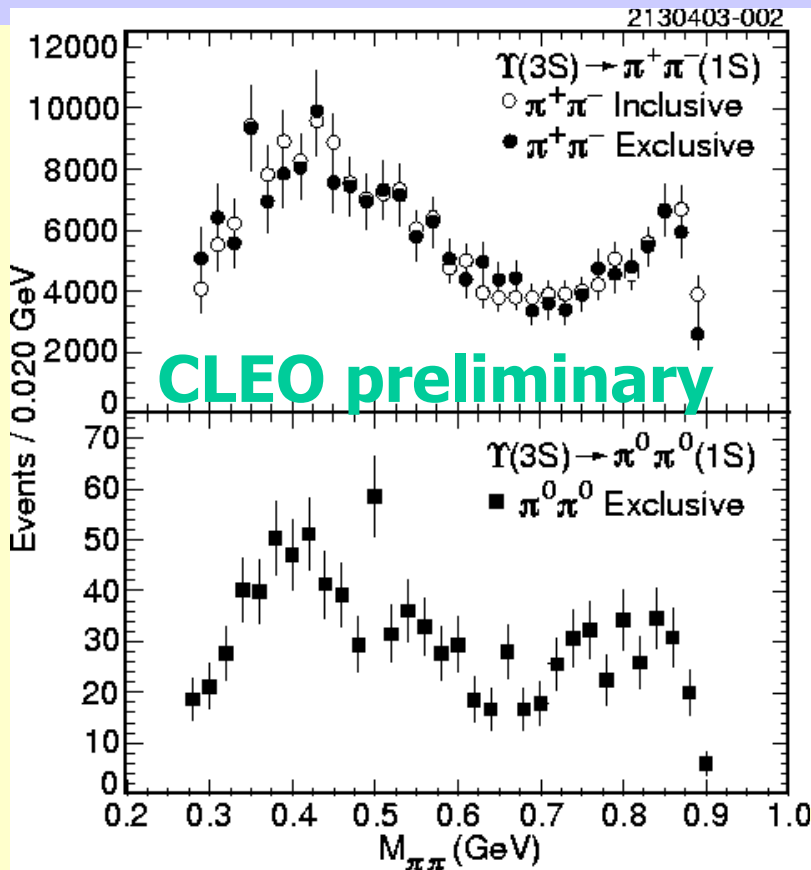
No charge involved:

- two charged pions
or
- neutral particles
 - ▶ $\pi^0 \pi^0$
 - ▶ Single π^0 transitions
isospin **suppressed**
 - ▶ η, ω are rare



Υ Dipion transitions

New $\Upsilon(3S) \rightarrow \Upsilon(1S)\pi\pi$ data:



Moxhay, PRD39(1980)3497: generic, constant, complex amplitude coupling to $B\bar{B}^*$ states and interfering with the multipole expansion amplitude

$\Upsilon(3S)$ rare hadronic transitions

$$\Upsilon(3S) \rightarrow \pi\pi\pi \Upsilon(1S) + X$$

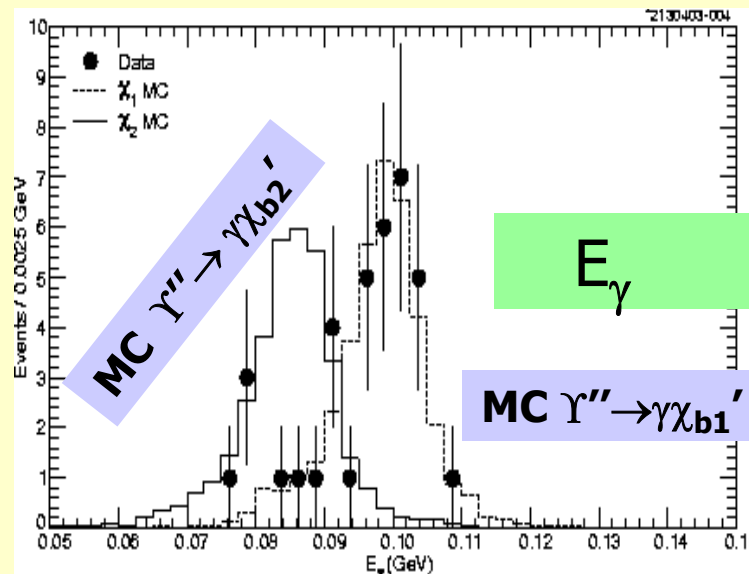
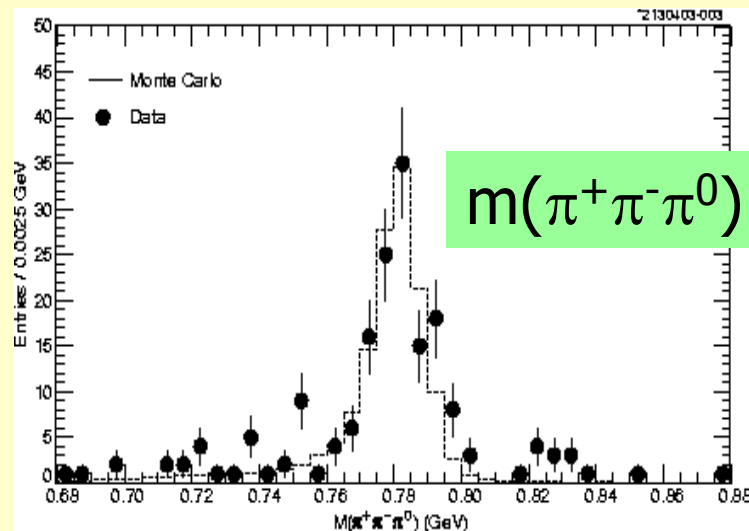
- $\pi^+\pi^-\pi^0$ distribution peaks at ω , X is photon
- Data consistent with $\Upsilon(3S) \rightarrow \gamma\chi_{b1}'$, $\chi_{b1}' \rightarrow \omega\Upsilon(1S)$. Small χ_{b2}' admix not excluded
- $B(\chi_{b1}' \rightarrow \omega\Upsilon(1S)) = (2.3 \pm 0.4(\text{stat}))\%$

Substantial!

$$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-: \gamma\gamma \text{ from } \pi^0/\eta?$$

- $B(\Upsilon'' \rightarrow \pi^0\Upsilon) < 0.17 \times 10^{-3}$
- $B(\Upsilon'' \rightarrow \eta\Upsilon) < 0.9 \times 10^{-3}$
- $B(\Upsilon'' \rightarrow \pi^0\Upsilon') < 1.2 \times 10^{-3}$

$$\begin{aligned} \psi' &\rightarrow \eta J/\psi \sim 3\%, \\ \psi' &\rightarrow \pi^0 J/\psi \sim 0.1\% \end{aligned}$$

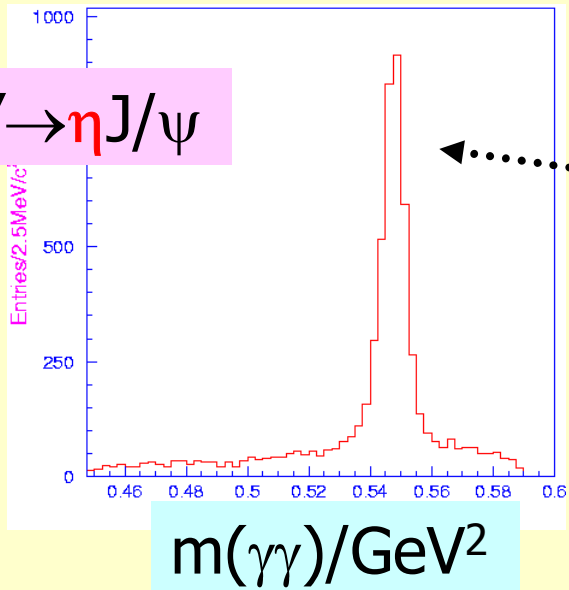


All results CLEO preliminary

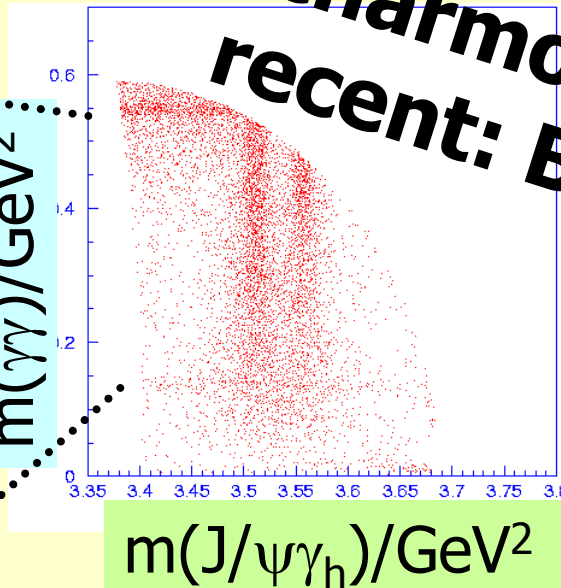
First hadronic non-pionic transition in bottomonium!
 First non-radiative decay of χ_b'

η, π^0 transitions in charmonium (most recent: BES, 14M ψ')

$\psi' \rightarrow \eta J/\psi$



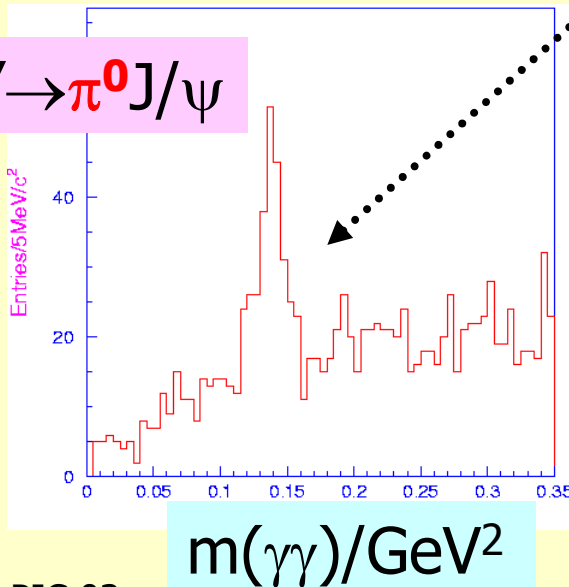
$m(\gamma\gamma)/\text{GeV}^2$



$m(J/\psi\gamma_h)/\text{GeV}^2$

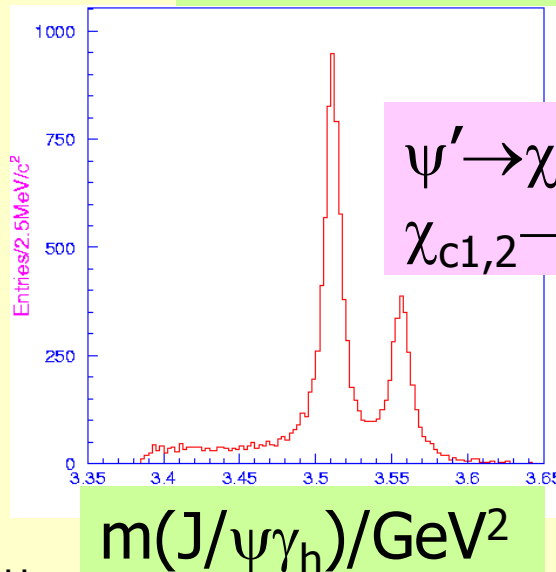
$\psi(2S) \rightarrow \gamma\gamma J/\psi,$
 $J/\psi \rightarrow \ell^+\ell^-$

$\psi' \rightarrow \pi^0 J/\psi$



$m(\gamma\gamma)/\text{GeV}^2$

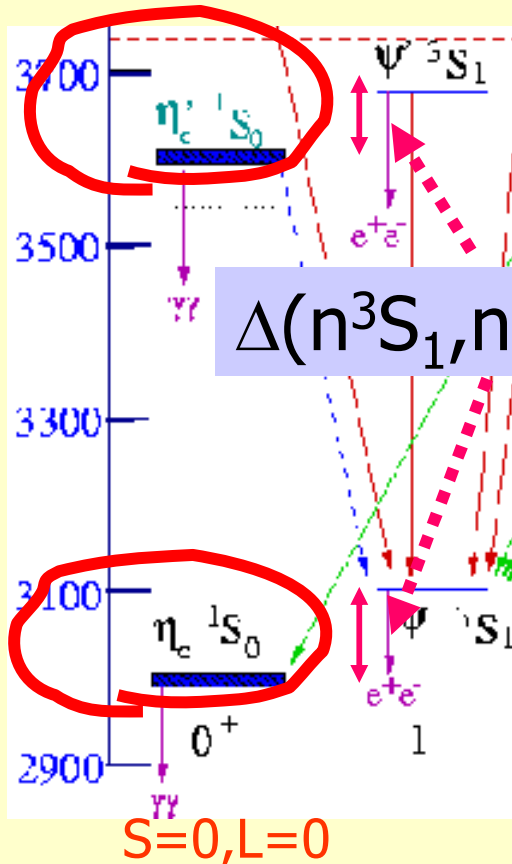
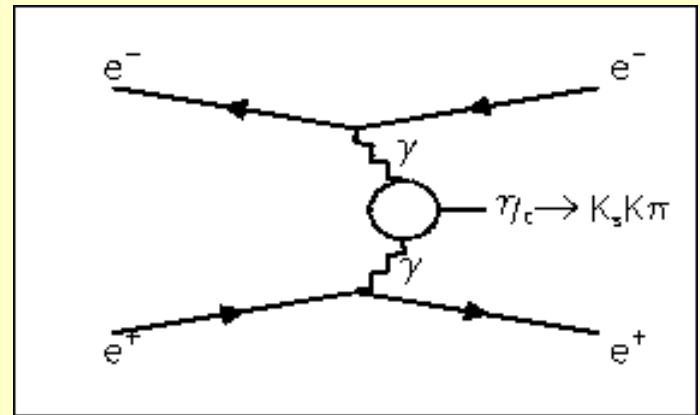
$\psi' \rightarrow \chi_{c1,2}\gamma,$
 $\chi_{c1,2} \rightarrow \gamma J/\psi$



$m(J/\psi\gamma_h)/\text{GeV}^2$

BES
 prelim,
 CERN
 Courier
 12/2002

n^1S_0 (η_c, η_c'): what 'n' why



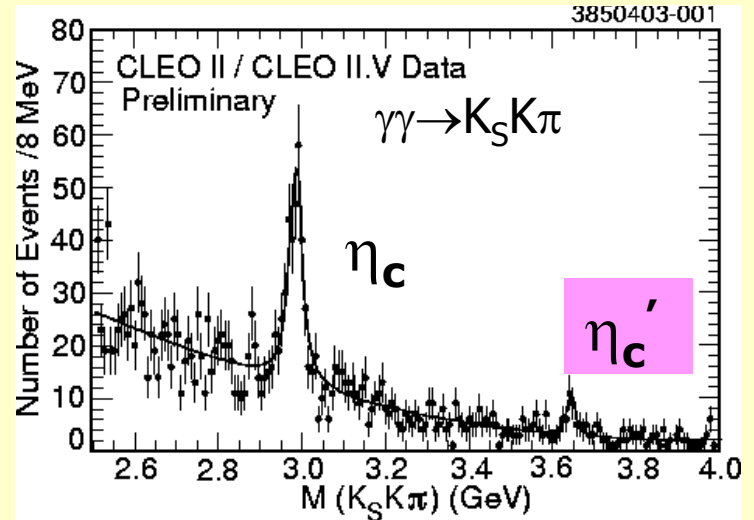
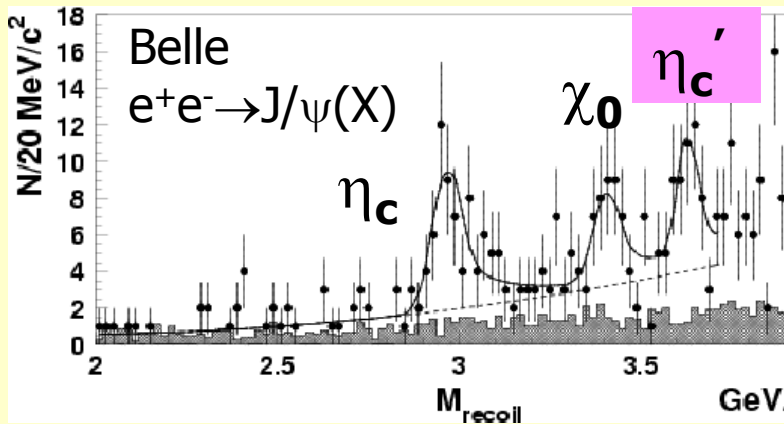
Produced in $\gamma\gamma$ collisions

η_c well established,

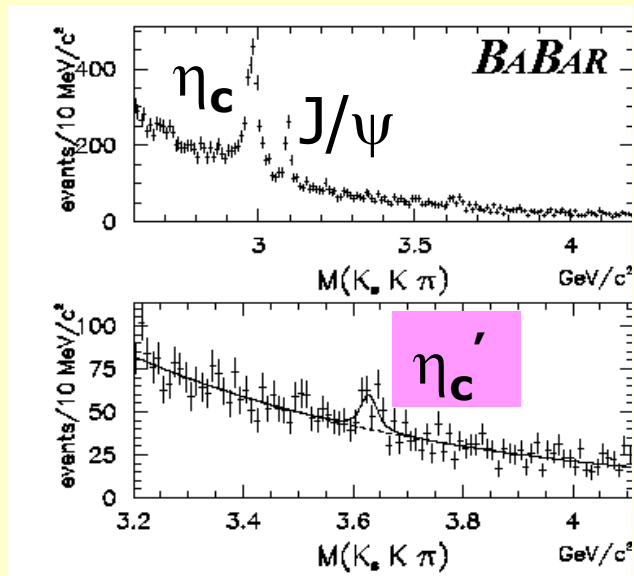
η_c' confirmed

❖ Potential Models predict
 $m(\eta_c') = 3594..3629 \text{ MeV}$

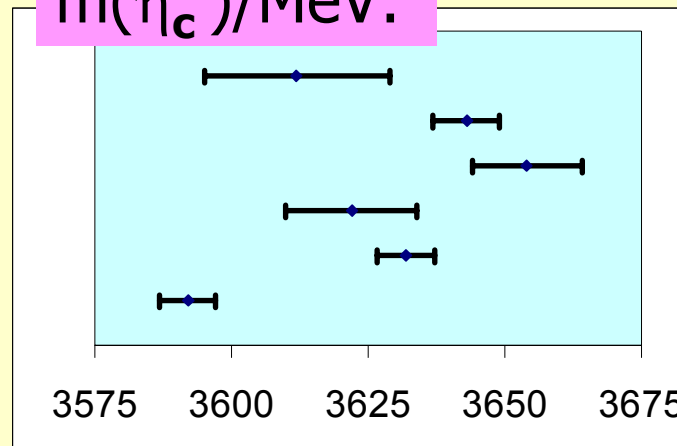
Recent Experimental Information on η_c'



CBAL PRL48(1982)70,
 BaBar hep-ex/0305083,
 Belle PRL89(2002)102001
 and PRL 89(2002)142001

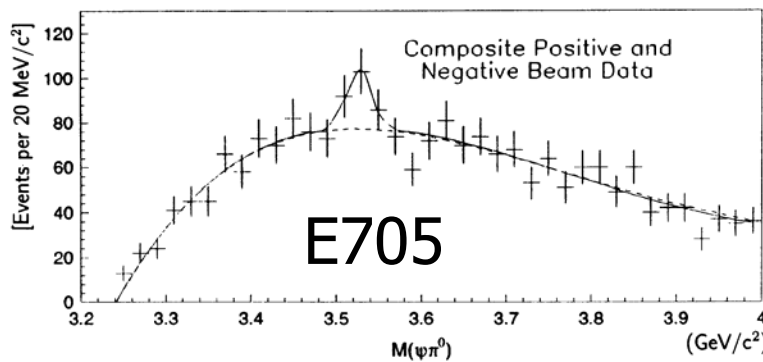


$m(\eta_c')/\text{MeV}:$

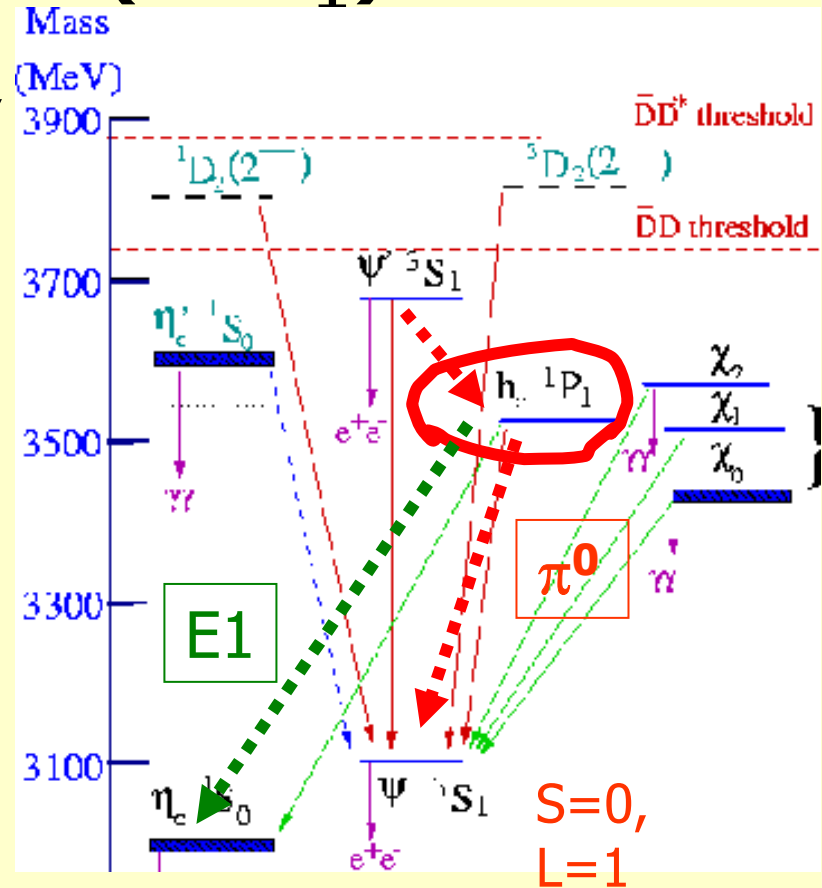


Potential models
CLEO $\gamma\gamma \rightarrow K_S K\pi$
Belle $B \rightarrow K(K_S K\pi)$
Belle $e^+e^- \rightarrow J/\psi(X)$
BaBar $\gamma\gamma \rightarrow K_S K\pi$
Crystal Ball 1982

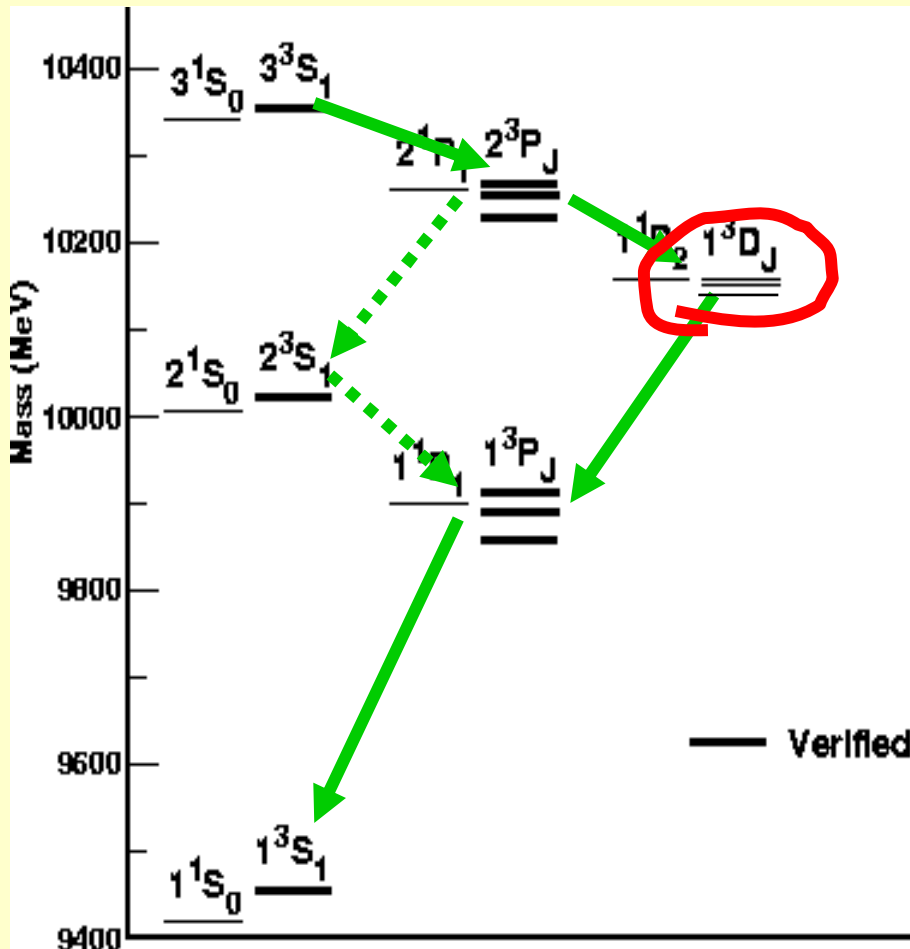
Where is the h_c (1^1P_1) ?



- PDG: “needs confirmation”
- E705: 2.5σ enhancement at 3.527 GeV [PRD50\(1994\)4258](#)
- E760: bump around 3.526 GeV [PRL69\(1992\)2337](#)
- **Prediction:** [PRD37\(1988\)1210](#)
 $B(\psi' \rightarrow h_c \pi^0) \sim 3.7 \times 10^{-3}$,
 $B(h_c \rightarrow \gamma \eta_c) \geq 50\%$



Discovery: $\Upsilon(1D)$ states

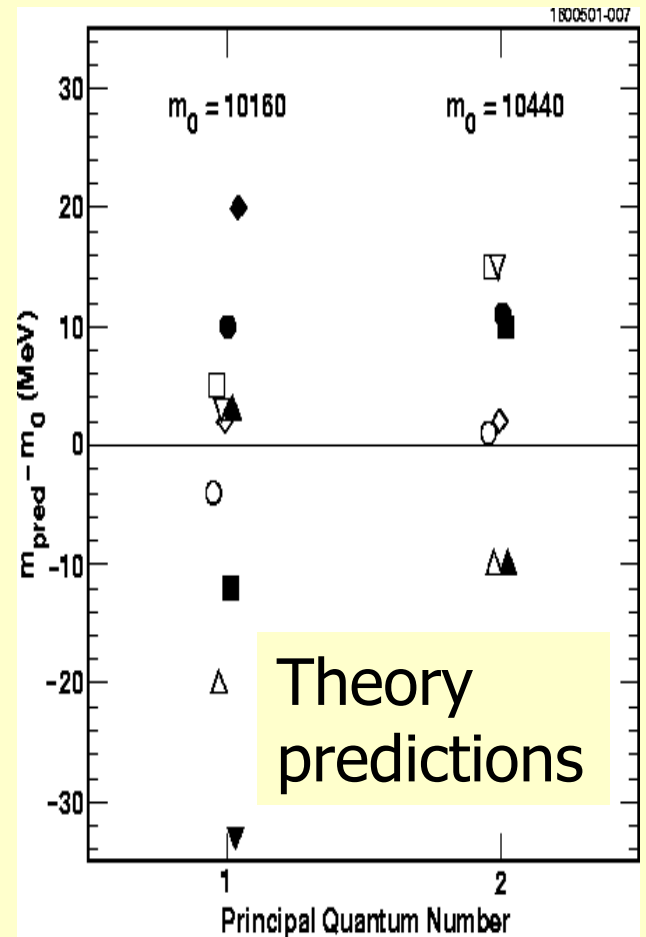


- Unique (L=2 and stable)
- Decays: electromagnetic (dominant, exception!) or via gluon annihilation (tiny)
- Look for $\Upsilon(3S) \rightarrow 4\gamma \Upsilon(1S)$
- Theory check: LCSR, LQCD predict masses; models tuned on L=0,1 states
 - LQCD gets this new state right!

CLEO $\Upsilon(1^3D_J)$ measurement

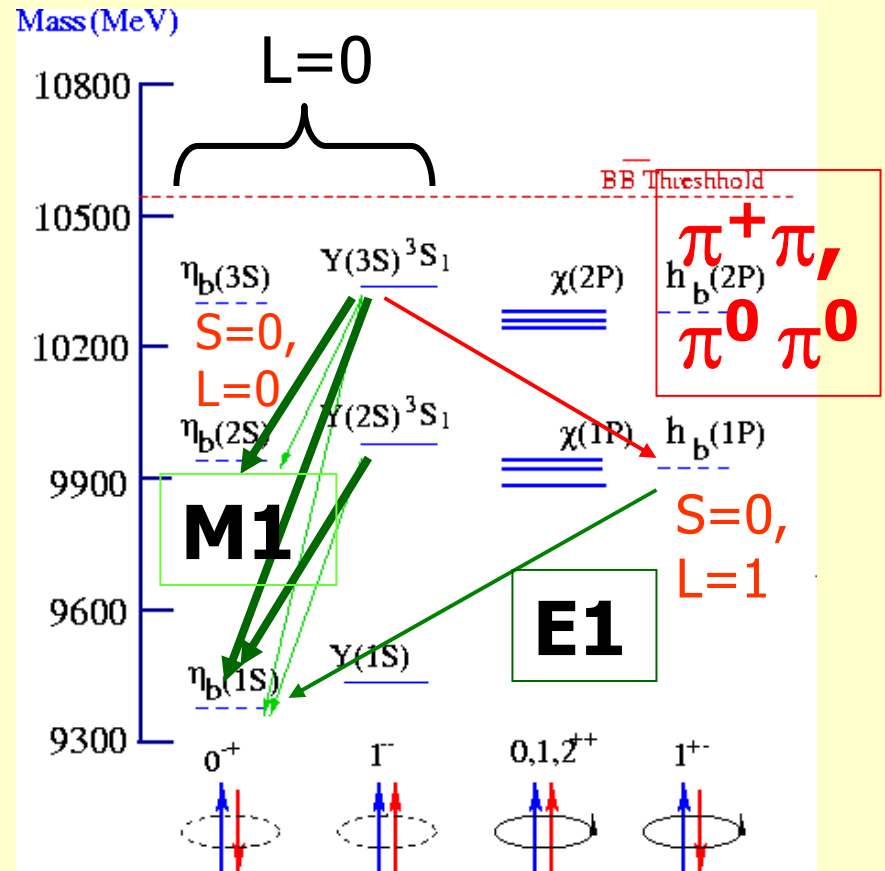
- See state at $10162.2 \pm 1.6 \text{ MeV}$ at 6.8σ : $J=1,2,3$?
 - inconsistent with $J=3$
 - Theory: $\Upsilon(1^3D_2)/\Upsilon(1^3D_1)=6$
 - $\Upsilon(1^3D_2)$ most likely
- Consistent with predictions for $\Upsilon(1^3D_2)$ to lie $0.5..1 \text{ MeV}$ below multiplet c.o.g.
- **First new $b\bar{b}$ state in 19 years!**

n^3D_J c.o.g. – m_0 (MeV)



Υ singlet states: $\eta_b('), h_b$

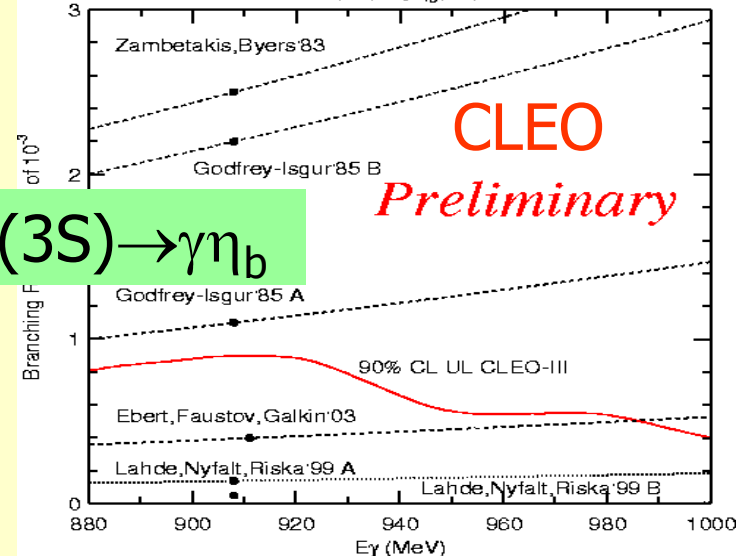
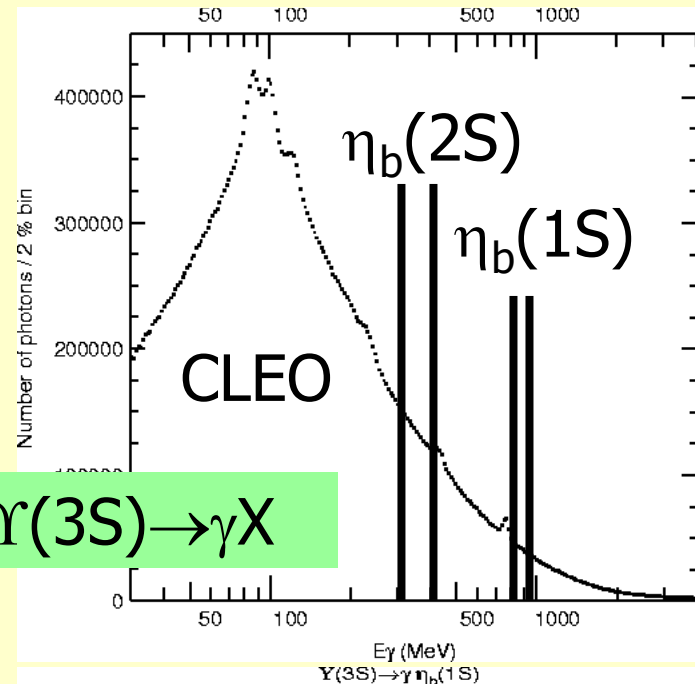
- Singlet states (n^1S_0, n^1P_1) not yet seen in $b\bar{b}$ (n^1S_0 seen in $c\bar{c}$)
- Hyperfine splitting ($n^1S_0 \leftrightarrow n^1S_1 = \Upsilon(nS)$; $n^1P_1 \leftrightarrow n^1P_{1,2,3} = \chi_{b1,2,3}$) predicted by LQCD and potential models
- η_b quasi-stable ($b\bar{b} \rightarrow gg$)
- E1 transitions well known
- Use hindered M1 transitions (ΔE larger)

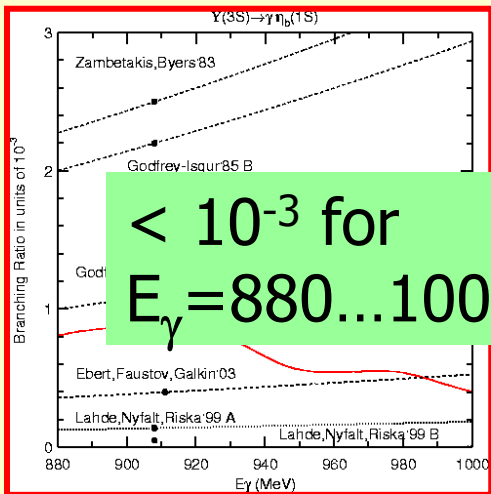


η_b, η_b' searches through hindered M1 transitions

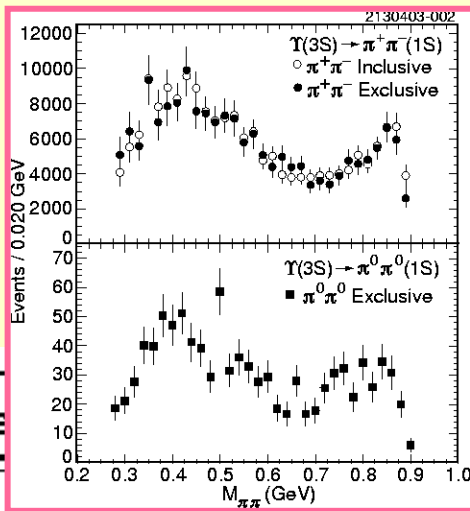
E_γ peaks in $\Upsilon(2,3S) \rightarrow \gamma X$:
 mass \rightarrow level splitting,
 amplitude \rightarrow transition BR

- $1\text{fb}^{-1} \Upsilon(3S), 0.5\text{fb}^{-1} \Upsilon(1S)$ CLEOIII data
- E1 transitions in that region well known
- No significant signal found, upper limits computed as function of photon energy

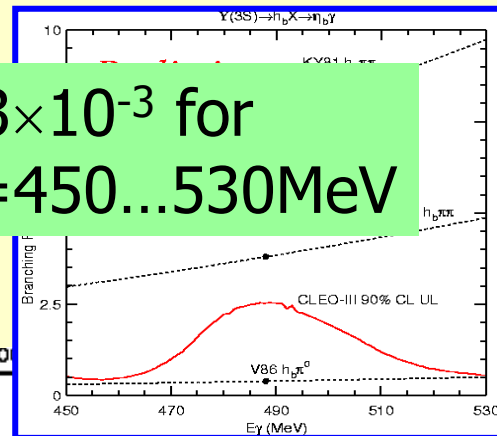




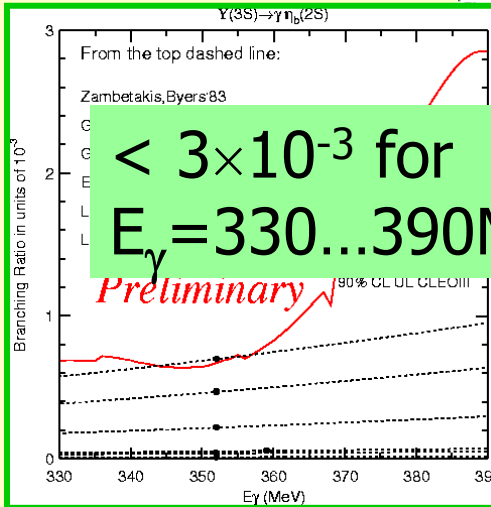
$< 10^{-3}$ for
 $E_\gamma = 880 \dots 1000 \text{ MeV}$



$< 3 \times 10^{-3}$ for
 $E_\gamma = 450 \dots 530 \text{ MeV}$

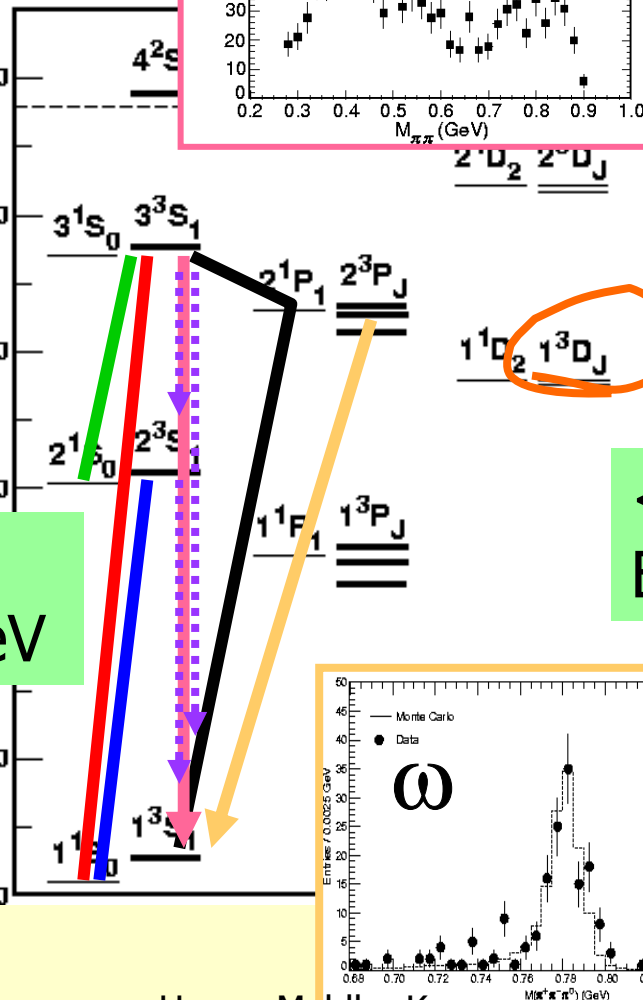


η, π^0 transitions
 $< 10^{-3}$



$< 3 \times 10^{-3}$ for
 $E_\gamma = 330 \dots 390 \text{ MeV}$

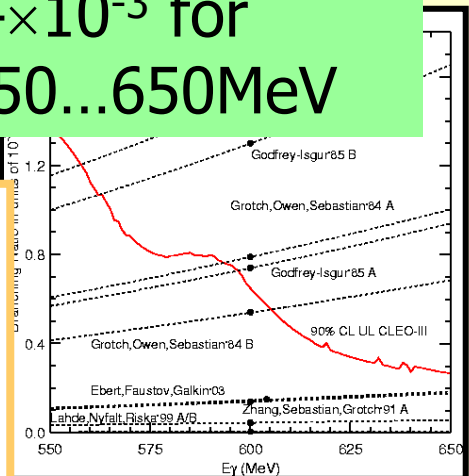
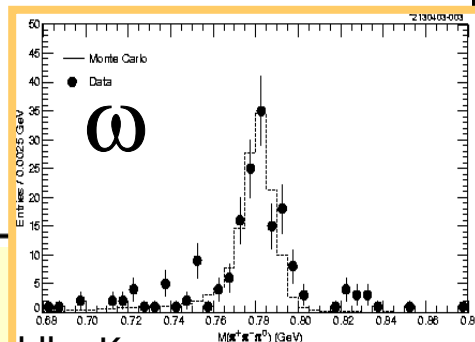
Preliminary

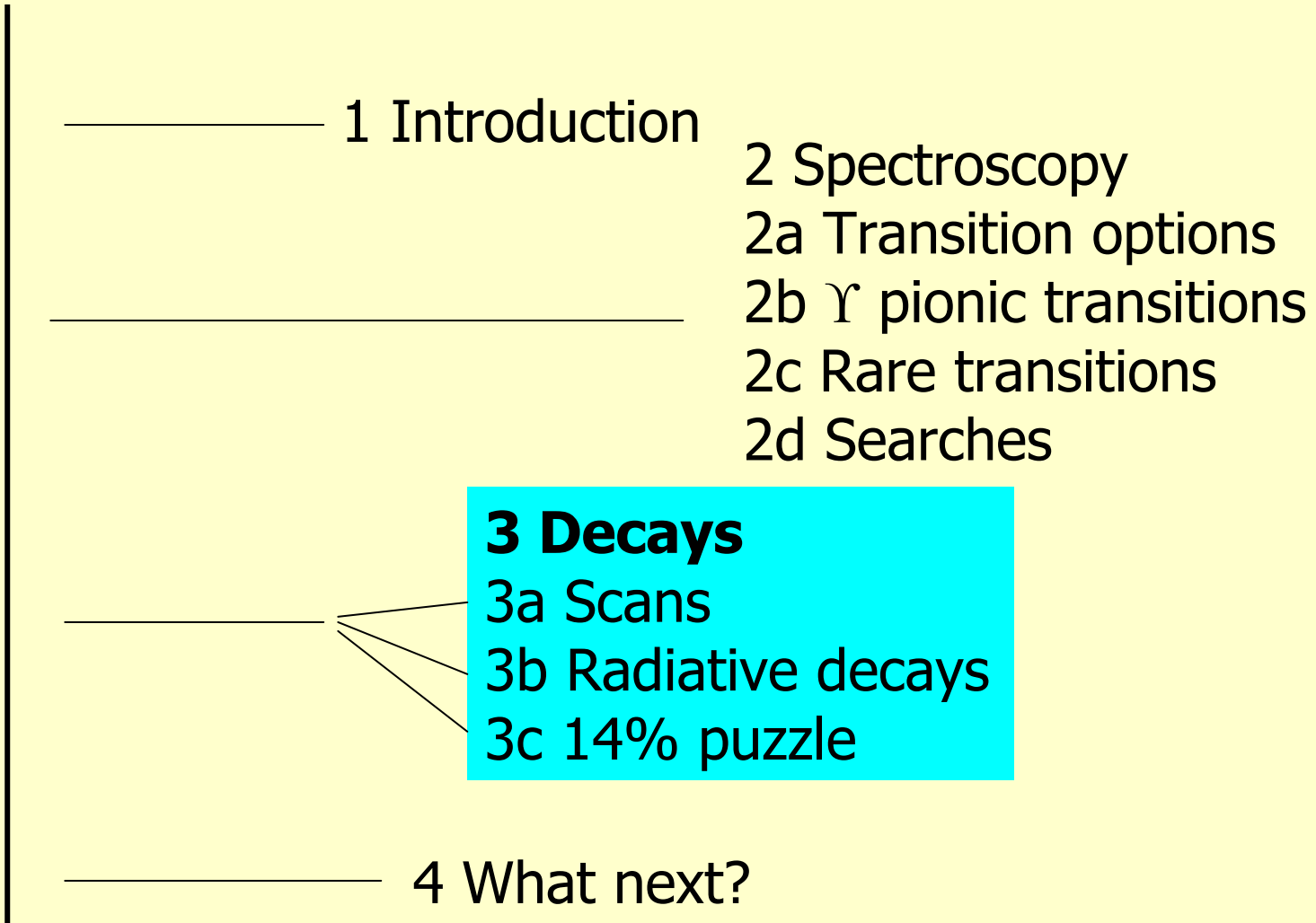


$Y(1D_2)$ at 6.8σ :
 $10162.2 \pm 1.6 \text{ MeV}$

CLEO

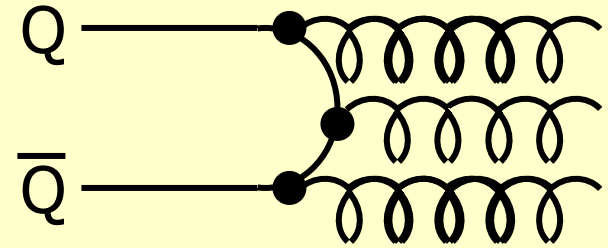
$< 1.4 \times 10^{-3}$ for
 $E_\gamma = 550 \dots 650 \text{ MeV}$



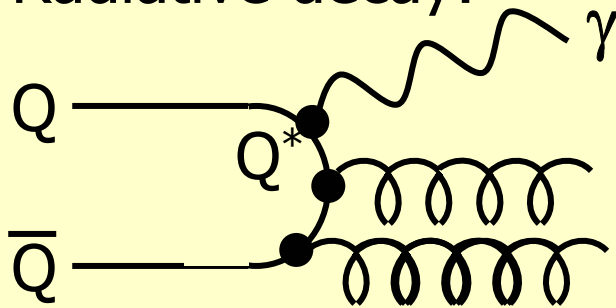


$Q\bar{Q}$ decays into light hadrons

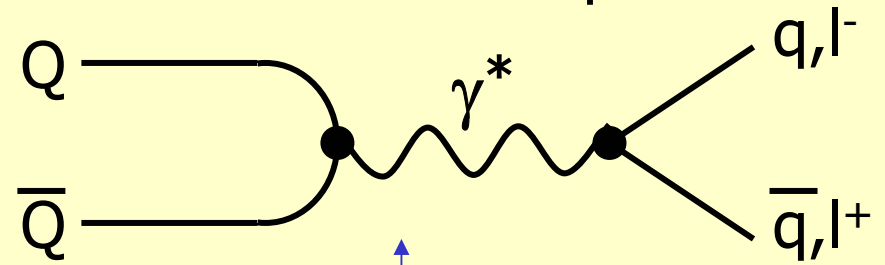
Annihilation into 3g:



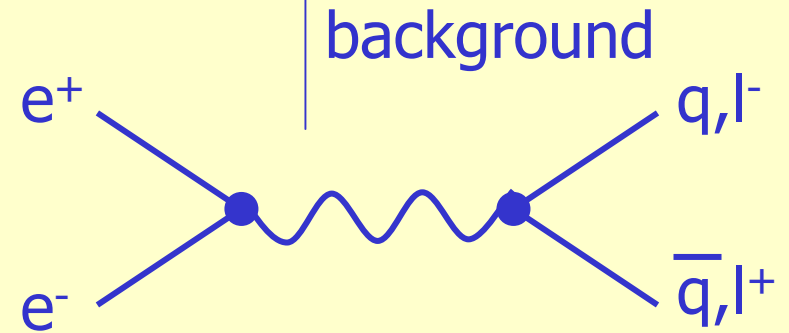
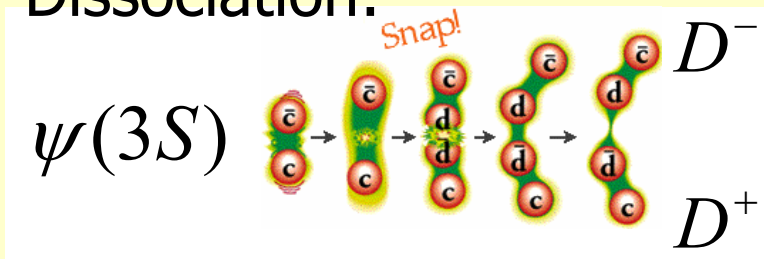
Radiative decay:



Annihilation into a photon:



Dissociation:



Continuum interference

P.Wang, CZ.Yuan, XH.Mo, DH.Zhang,
hep-ph/0212139, Phys.Lett.B557(2003)192

A problem in e^+e^- : $e^+e^- \rightarrow \gamma^* \rightarrow \text{light hadrons}$
interferes with $e^+e^- \rightarrow Q\bar{Q} \rightarrow \text{light hadrons}$

➤ Resonance + continuum + interference terms

- Recent work suggests substantial corrections to get from measured to desired quantity, e.g.

$$B(\psi(2S) \rightarrow \omega\pi^0) = (3.8 \pm 1.7 \pm 1.1) \times 10^{-5} \rightarrow -58\%$$

- Dependence on experimental conditions:
large beam energy spread allows more continuum+interference in;
tight FS invariant mass requirements prevent ISR $q\bar{q}$ contamination
- Not the same for every channel
- **Off-resonance data is costly but necessary.**

BES ψ' Scan

PLB550(2002)24

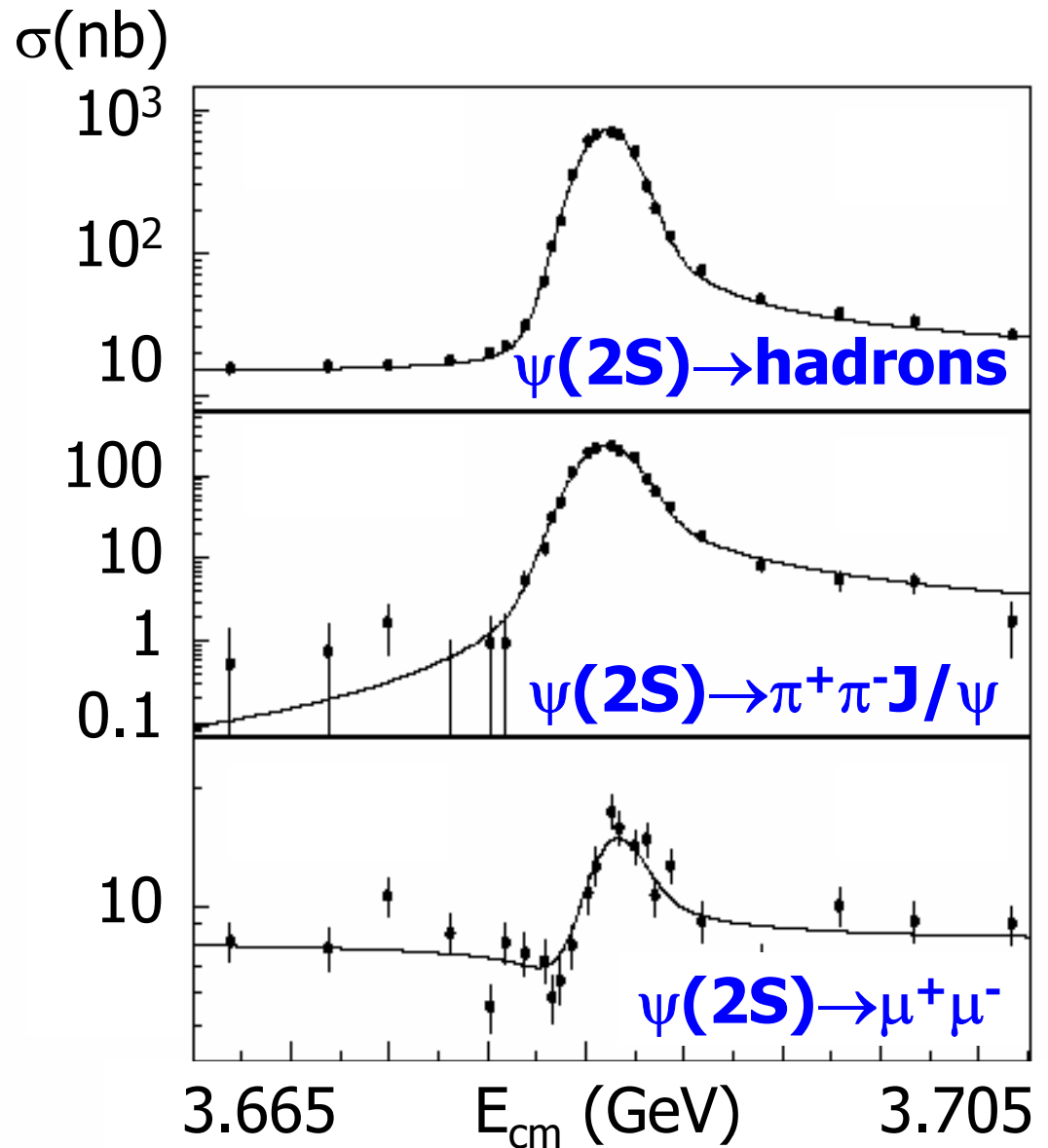
- Precision improvement
- BR's as input to other experiments

• Measure

$\Gamma_{\text{tot}}, \Gamma_{\ell\ell}, \Gamma_{J/\psi\pi\pi}$

infer $\Gamma_{\text{had}}, B_{\ell\ell}$

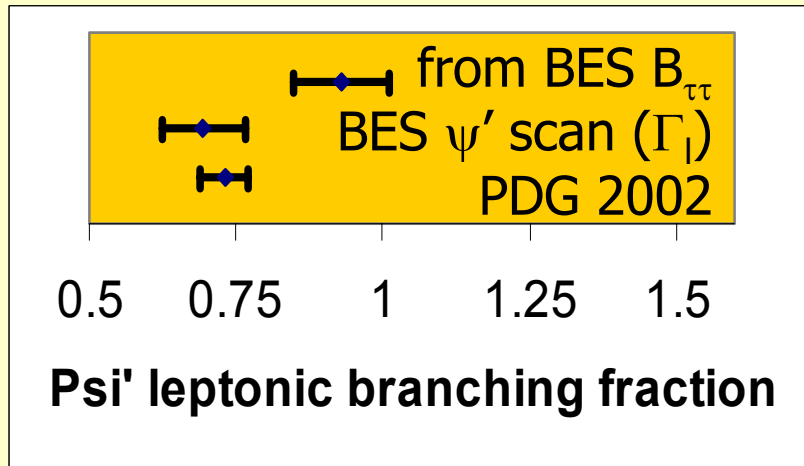
$B_{J/\psi\pi\pi}$



BES ψ' scan and τ data

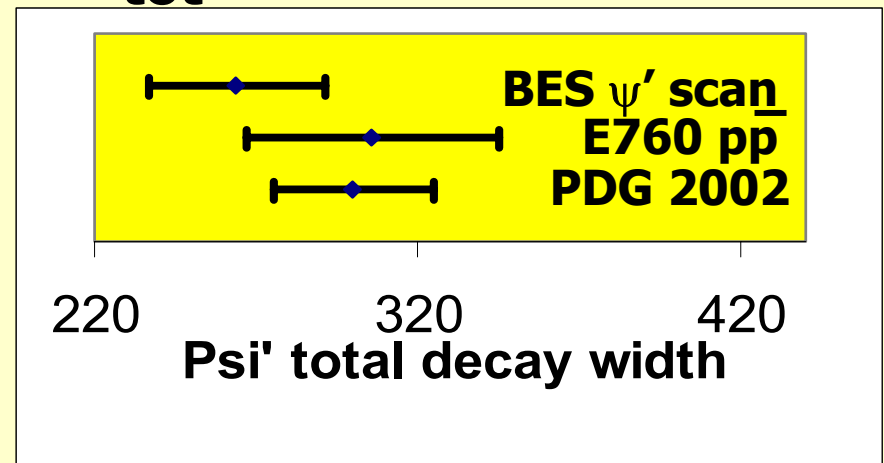
$$\frac{B_{ll}}{\beta_1 \left(\frac{3}{2} - \frac{1}{2} \beta_1^2 \right)} = \text{const}, \beta_1 = \left(1 - \frac{4m_l^2}{M_{\psi'}^2} \right)^{1/2}$$

$$B_{ee} \approx B_{\mu\mu} \approx B_{\tau\tau} / 0.3885:$$



PLB550(2002)24 (BES scan)
 PRD65(2002)052004 ($B_{\tau\tau}$)
 PRD47(1993)772 (E760 scan)

Γ_{tot}



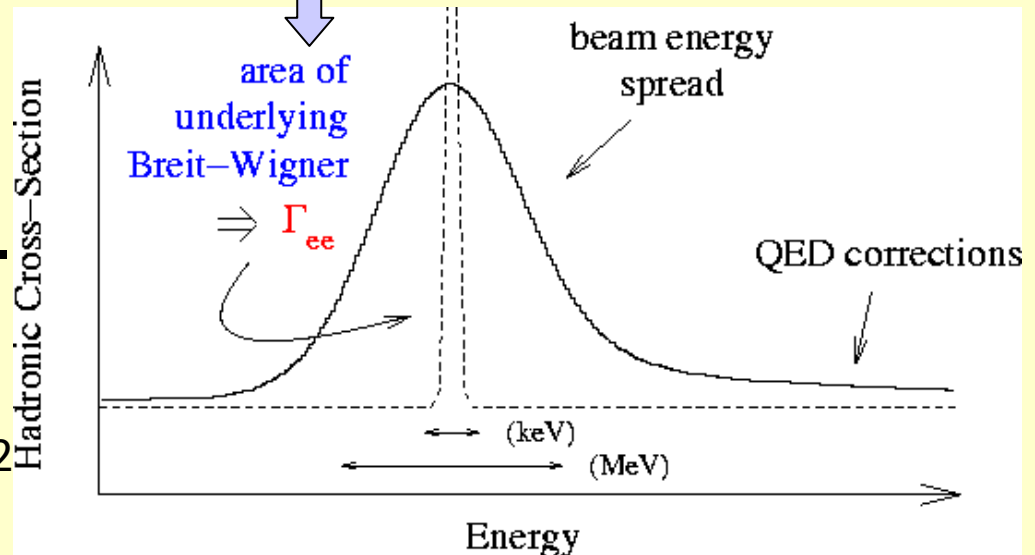
Leptonic $\Upsilon(1,2,3S)$ Width Γ_{ee}

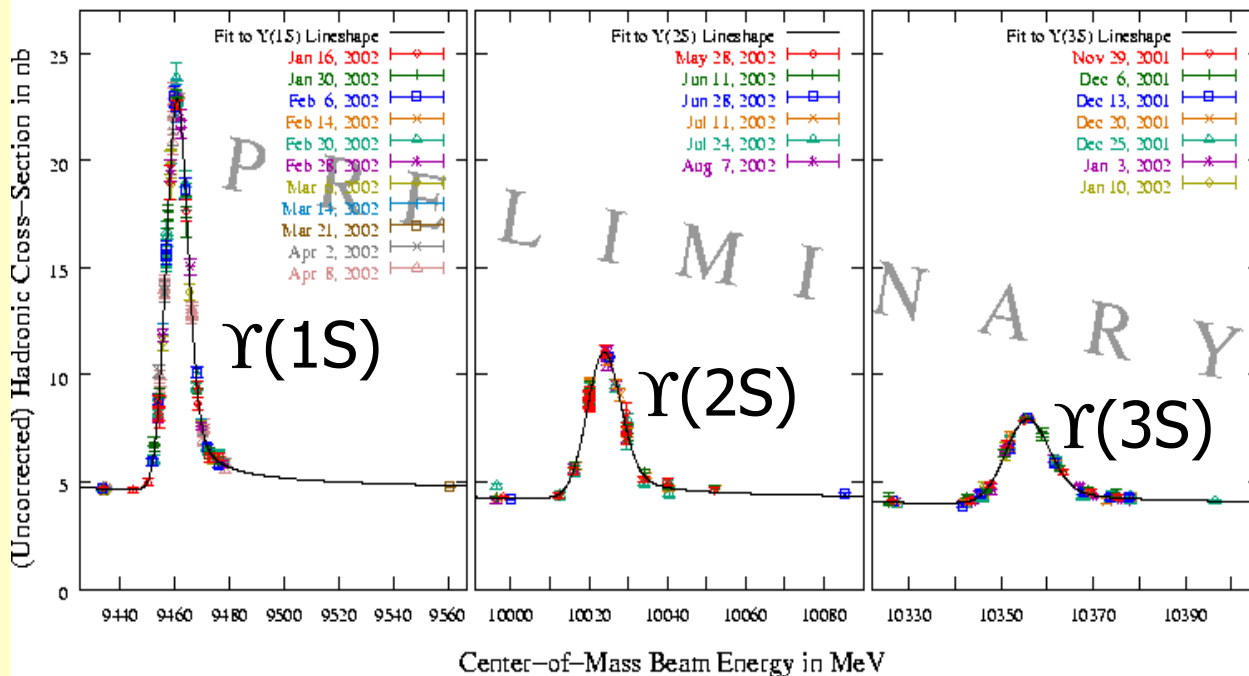
- High precision test for LQCD!
- Strategy:

$$\Gamma(Y \rightarrow e^+e^-) = \frac{M_Y^2}{6\pi^2} \underbrace{\frac{\Gamma_{\text{total}}}{\Gamma_{\text{hadrons}}}}_{\text{External input}} \int d\text{Energy} \sigma(e^+e^- \rightarrow Y \rightarrow \text{hadrons})$$

External
input

Hope to improve from
2/4/9% to better than 2%.
Correct for higher orders
 $\rightarrow \Gamma_{ee}^{(0)}$ to compare with
theory – challenge: $|\psi(0)|^2$



840 pb⁻¹450 pb⁻¹600 pb⁻¹

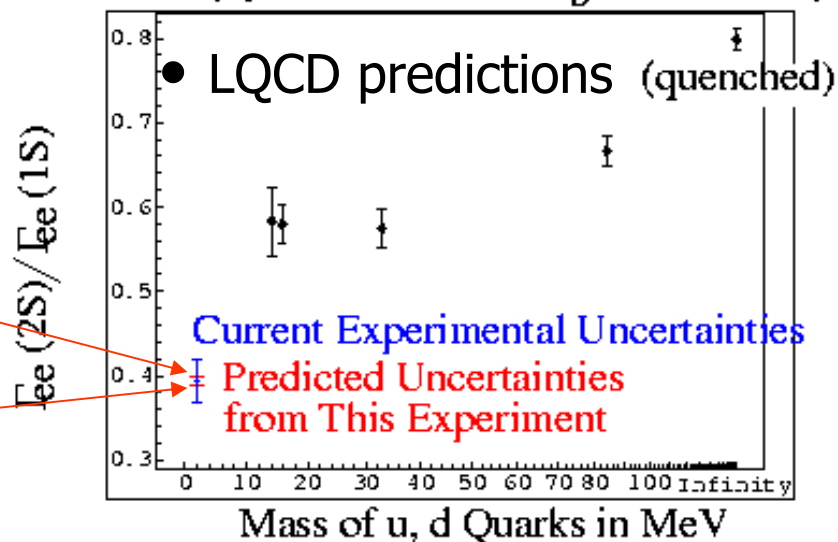
CLEO Υ scan

$$\Gamma_{ee}(2S)$$

$$\Gamma_{ee}(1S)$$

Statistical
precision:
0.1/0.3/0.5%

Note! Theory points have no $1/M_b$ corrections yet.

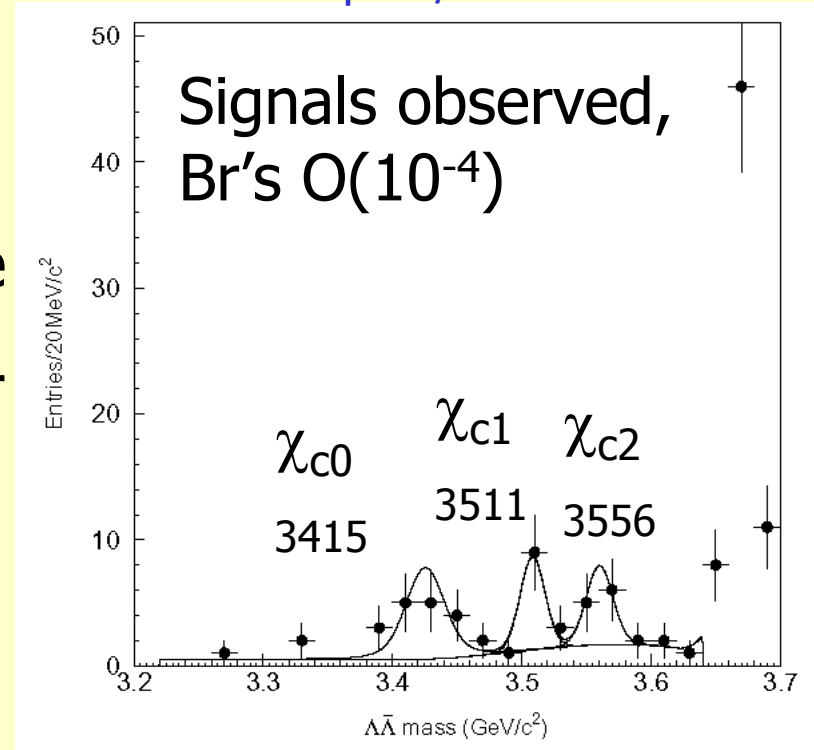


Radiative Decays

hep-ex/0304012

$$\chi_c \rightarrow \Lambda \bar{\Lambda}, J=0,1,2$$

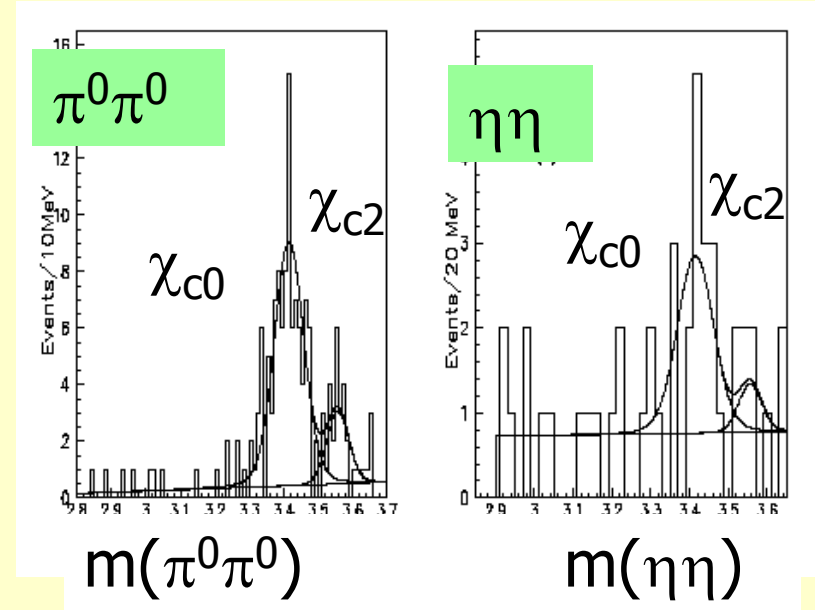
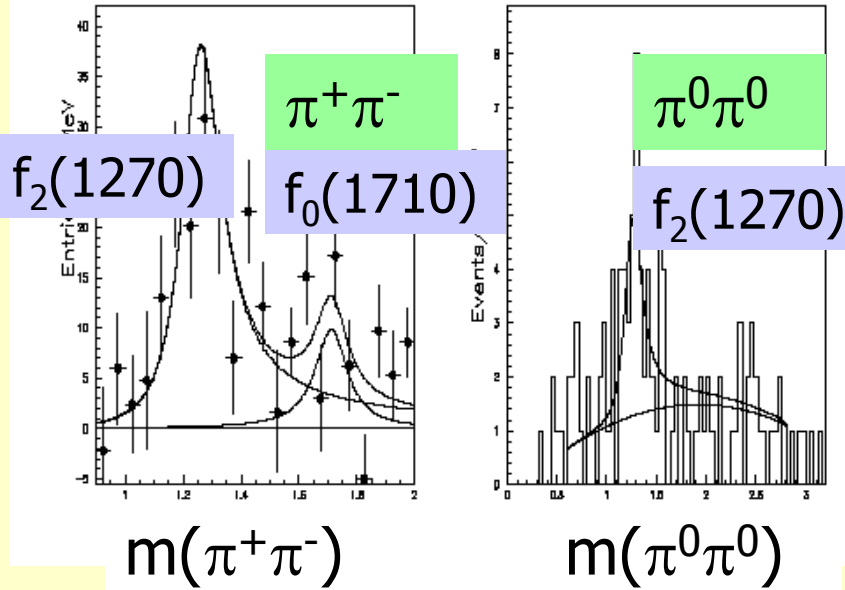
- ❖ Color Singlet Model found to be insufficient to describe P-wave quarkonium decays, need Color Octet Model.
- ❖ $\Gamma(\chi_c \rightarrow p\bar{p}, \text{Color Octet Model}) \approx \Gamma(\chi_c \rightarrow p\bar{p}, \text{experiment})$
- ❖ COM:
 $\Gamma(\chi_{c1,2} \rightarrow \Lambda \bar{\Lambda}) / \Gamma(\chi_{c1,2} \rightarrow p\bar{p}) = 1/2.$



	χ_{c0}	χ_{c1}	χ_{c2}
$B(\chi_{cJ} \rightarrow \Lambda \bar{\Lambda}), 10^{-4}$	$4.7 \pm 35\%$	$2.6 \pm 45\%$	$3.3 \pm 50\%$
$B(\chi_{cJ} \rightarrow \Lambda \bar{\Lambda}) / B(\chi_{cJ} \rightarrow p\bar{p})$	2.2 ± 1.2	3.7 ± 2.3	4.7 ± 3.0

$\psi' \rightarrow \gamma P \bar{P}, P = \pi, K, \eta$

BES, Phys.Rev.D67:032004,2003

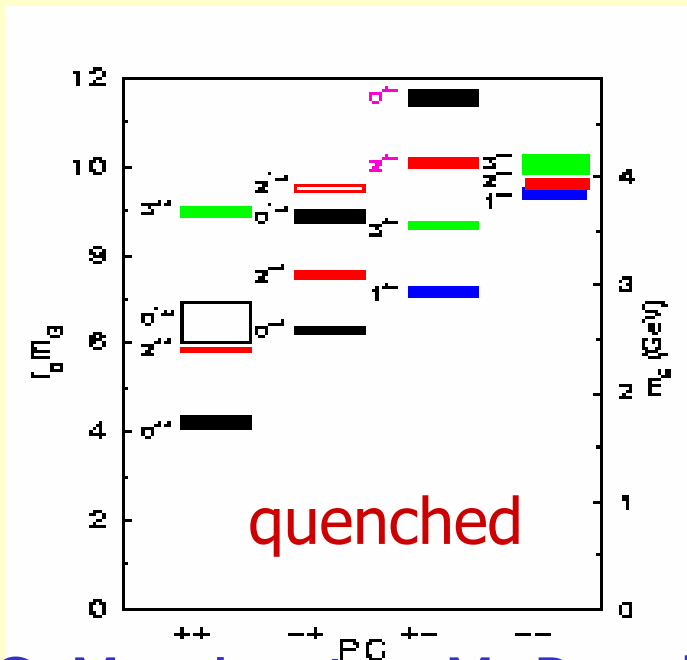
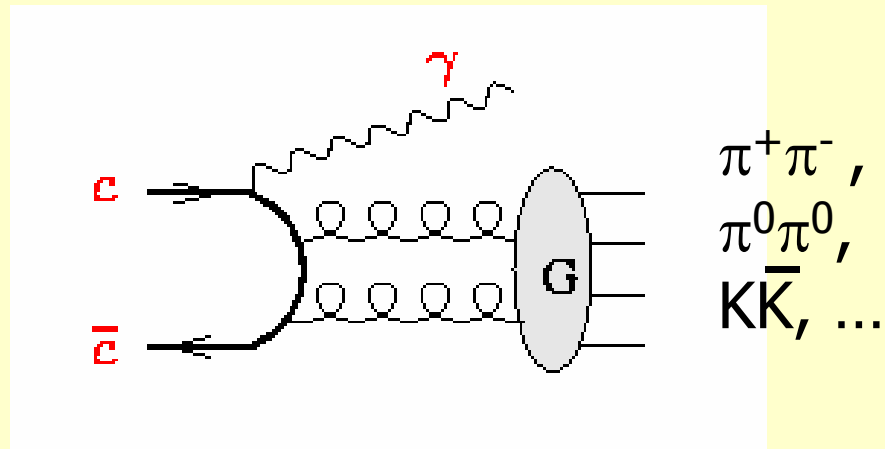


$$B(\psi' \rightarrow \gamma f_2(1270)) = (2.27 \pm 0.26 \pm 0.39) \times 10^{-4} \text{ (21\%)}$$

$$B(\psi' \rightarrow \gamma f_0(1710)) \times B(f_0(1710) \rightarrow KK, \pi\pi) \leq 10^{-5} \text{ (90\%CL)}$$

BR × 10⁻³	J=0	J=2
$\chi_{cJ} \rightarrow \pi^0\pi^0$	2.65 ± 25%	0.87 ± 64%
$\chi_{cJ} \rightarrow \eta\eta$	1.94 ± 52%	< 1.22 (90%CL)
$\chi_{cJ} \rightarrow \eta\eta$	0.73 ± 60%	
$\chi_{cJ} \rightarrow \pi^0\pi^0$	SU(3): 0.95	

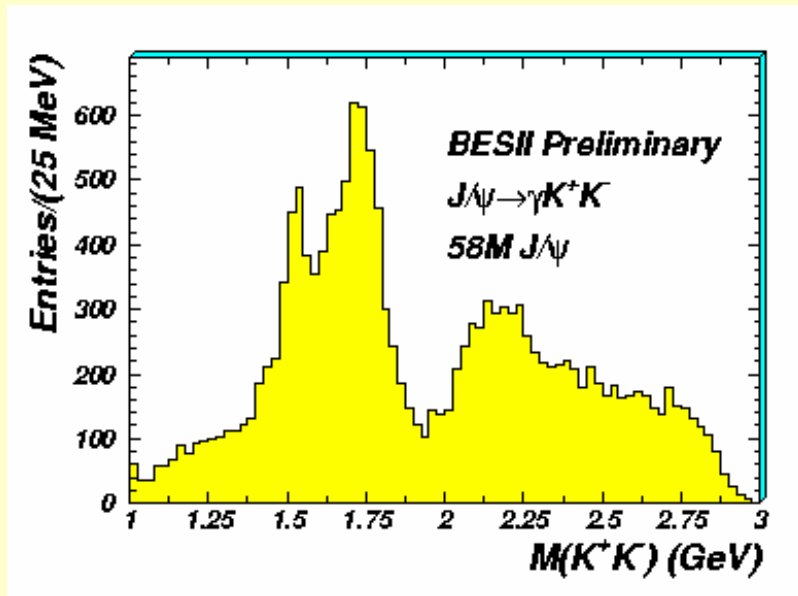
Radiative decays to glueballs: $J/\psi \rightarrow \gamma gg$



- Lowest candidate (0^{++}) around 1700 MeV, lowest 2^{++} around 2220 MeV
- Perform PWA to learn quantum numbers
- If glueball, then $\gamma\gamma$ should not show it (antisearch)

C. Morningstar, M. Peardon,
hep-lat/9901004

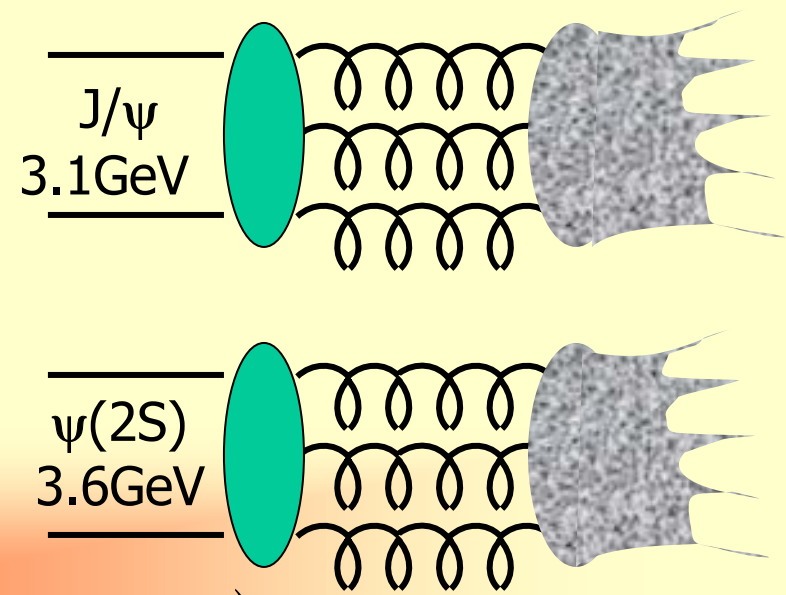
The $f_J(222[3]0)$



Wait for Cleo-c!

lowest tensor glueball near 2.2GeV, quite narrow:

- 1996: BES candidates in $\pi^+\pi^-$, K^+K^- , $K_S K_S$, $p\bar{p}$ modes
- Not confirmed by CBAL, JETSET
- BES is reinvestigating with 58M J/ψ
- At present no signal for a narrow state
- CLEO, LEP antiseached ✓
- CLEO: $\Upsilon(1S) \rightarrow \gamma f_J(2220)$



“The 14% puzzle”

- ❖ If mechanism is $c\bar{c} \rightarrow ggg$
 \Rightarrow decay rate $\sim |\Psi(0)|^2$

$$Q_h = \frac{B(\psi(2S) \rightarrow H)}{B(J/\psi \rightarrow H)} = \frac{\alpha_s^3(\psi(2S))}{\alpha_s^3(J/\psi)} \frac{B(\psi(2S) \rightarrow e^+e^-)}{B(J/\psi \rightarrow e^+e^-)} \approx (15 \pm 2)\%$$

known

- ❖ $B(ggg) + B(\gamma gg) + B(\gamma^* \rightarrow ee, \mu\mu, \tau\tau, \text{hadrons}) + B(c\bar{c}X) = 1:$

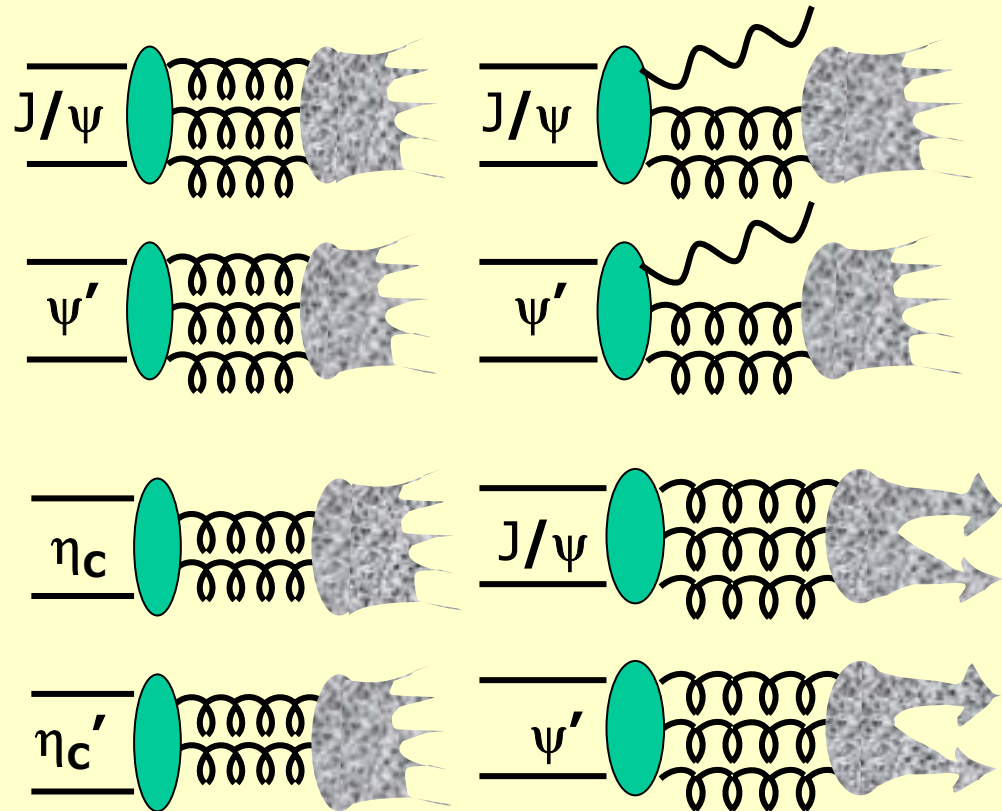
$$Q_h = \frac{B(\psi(2S) \rightarrow ggg) + B(\psi(2S) \rightarrow \gamma gg)}{B(J/\psi \rightarrow ggg) + B(J/\psi \rightarrow \gamma gg)} = (24.0 \pm 5.6)\%$$

(Gu, Li, hep-ph/9910406)

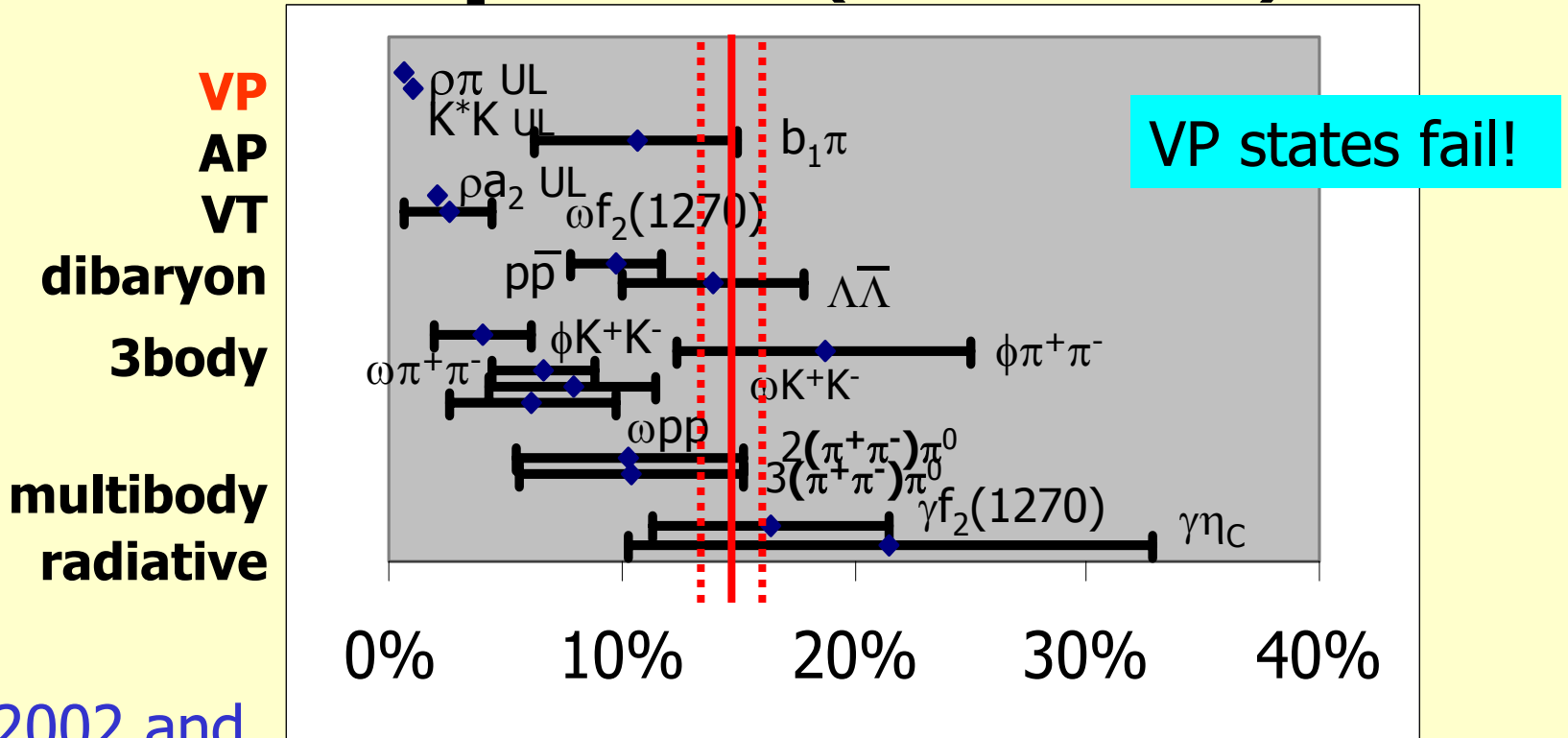
- ❖ **Deviations indicate presence of other mechanisms**

Applicability of the "14% rule"

- Should work for other singlet states
- Should work for radiative decays
- Sum or individual channels?
- Next: experimental data



Selected n^3S_1 data on the 14% puzzle (there is more)



PDG2002 and
PhysRevD67(2003)0520002

Hadron Helicity
Conservation
(Brodsky, Lepage,
Tuan)

Color-octet $c\bar{c}$
production (Chen
and Braaten)

Intrinsic
charm
(Brodsky,
Karlner)

$\psi' \rightarrow VP$
hindered M1
transitions
(Pinsky)

Glueball mixing
with J/ψ (Freund
and Nambu, Hou
and Soni)

Final State
Interactions
(Li, Bugg, Zou)

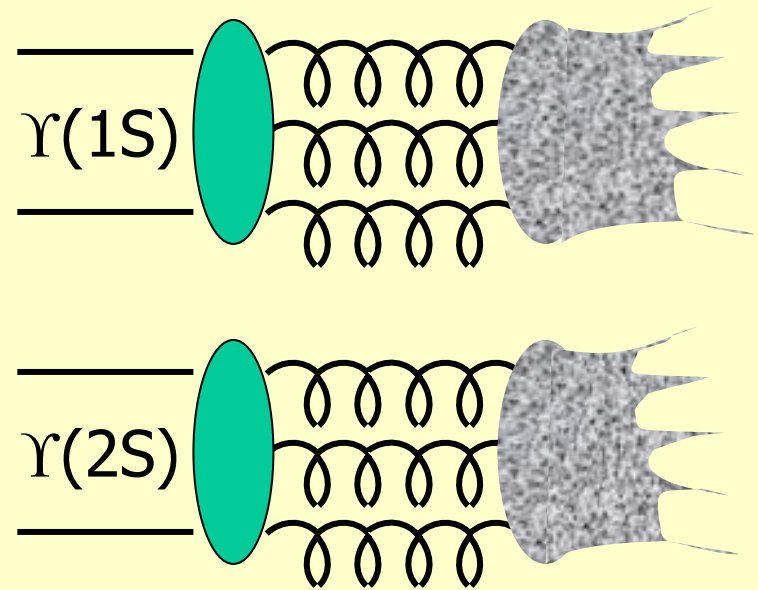
Glueball
mixing
with ψ'
(Suzuki)

Intrinsic charm
(Brodsky, Karlner)

Form factor
suppresses all
2body meson
modes (Chaichian,
Tornquist)

Exclusive hadronic Bottomonium decays, or the 14% puzzle for Υ

- Depending on model, $O(10^{-4..5})$ is expected for $\Upsilon \rightarrow \rho\pi$
- $\Gamma_{\parallel}(\Upsilon(2S)) / \Gamma_{\parallel}(\Upsilon(1S)) = 0.5/1.3 = 38\%$!
- CLEO is analyzing 20M $\Upsilon(1S)$, 10M $\Upsilon(2)$, 5M $\Upsilon(3S)$, searching for signals in PV final states



CLEO Preliminary $\Upsilon \rightarrow h_1 h_2$ Branching Fractions

Upper Limits at 90% CL in 10^{-5}

Mode/Region	1S	2S	3S
$\rho \pi$	0.5	1	2
$K^*(892) \bar{K}$	1	0.9	2
$\rho a_2(1320)$	2	2	3
$K^*(892) \bar{K}_2^*(1430)$	2	4	3
$\omega f_2(1270)$	0.7	1	0.8
$b_1(1235)\pi$	0.8	1	2
$K_1(1400) \bar{K}$	3	4	2

_____ 1 Introduction

2 Spectroscopy

2a Transition options

2b Υ pionic transitions

2c Rare transitions

2d Searches

3 Decays

_____ 3a Scans

3b Radiative decays

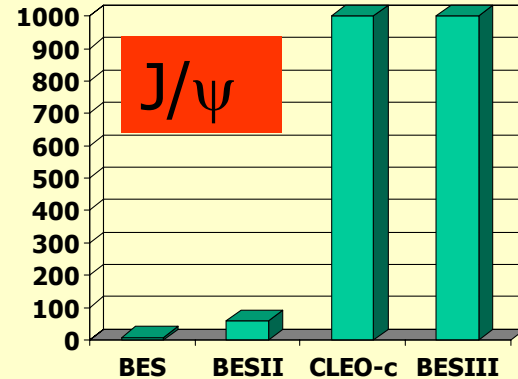
3c 14% puzzle

_____ **4 What next?**

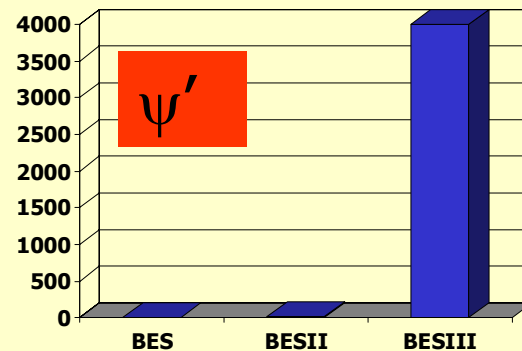
Upgrades, datasets

- CLEO $\Upsilon(1,2,3S)$ data taking over
- CLEO-c start-up right now, $\sqrt{s}=3..5\text{GeV}$, lumi $1\times 10^{-32}\text{s}^{-2}\text{cm}^{-1}$ at 3.1GeV
- BES/BEPC upgrade, $\sqrt{s}=2..5\text{GeV}$, lumi $1\times 10^{-33}\text{s}^{-2}\text{cm}^{-1}$ at 1.89GeV, data taking in 2006?

in 10^6 events



in 10^6 events



Puzzles

1 Introduction

2 Spectroscopy

h_c, h_b, η_b
 $\Delta m(\psi, \eta_c), n=1,2$
rare π, η transitions
E1 such as from χ_{b0}
...

3 Decays

η_c' decays
14% puzzle in $c\bar{c}$
14% puzzle in $b\bar{b}$
 $f_J(2220)$
...

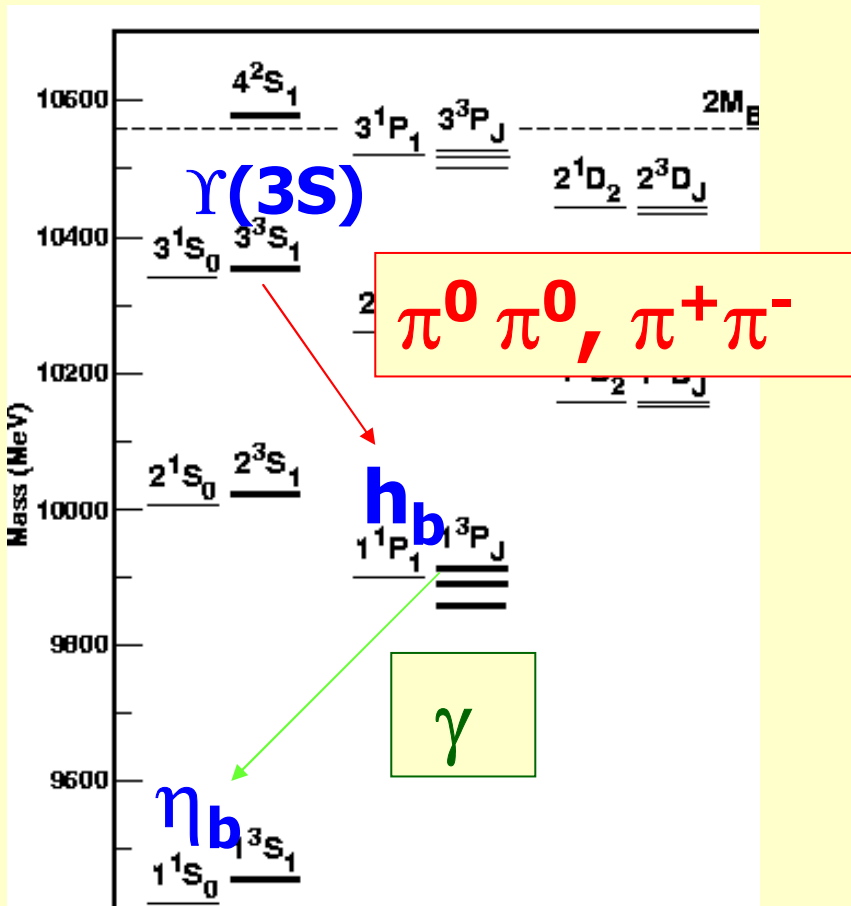
4 What next?

... and there are many more!

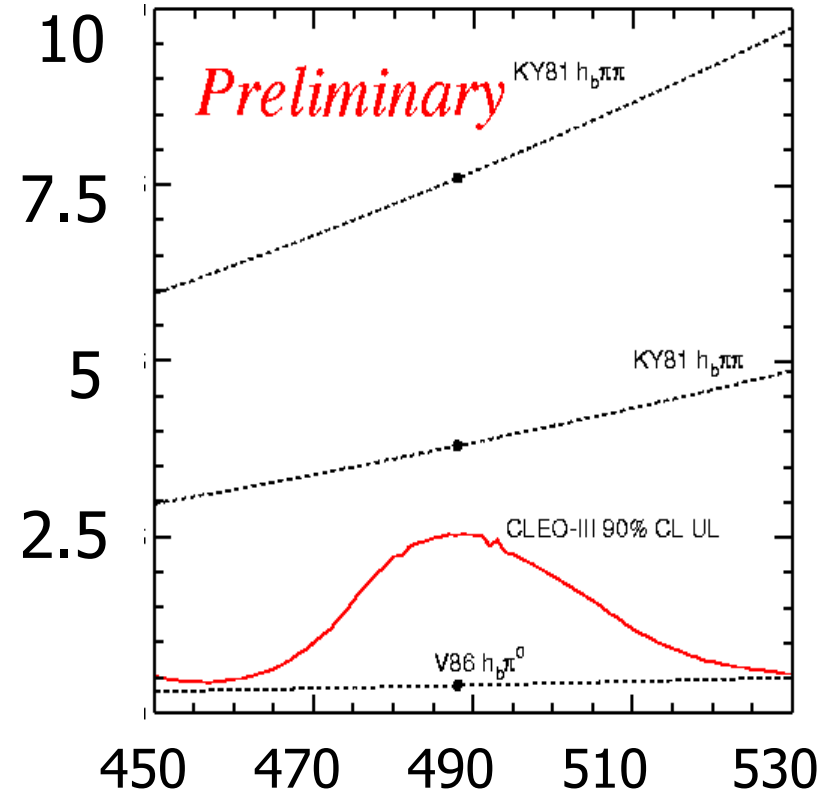
Summary

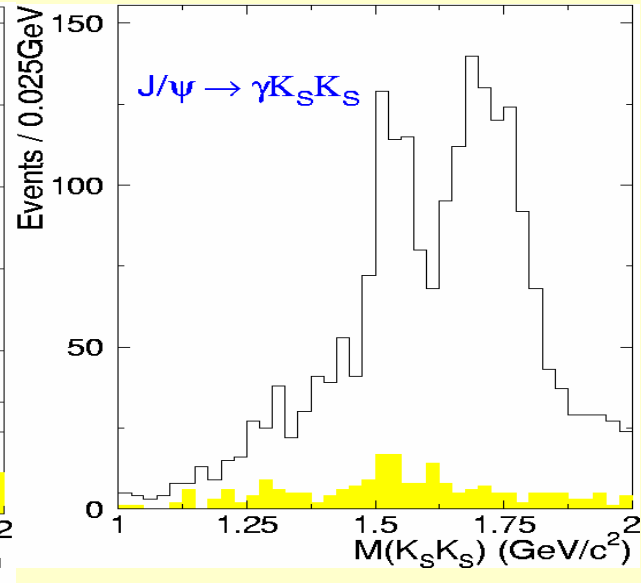
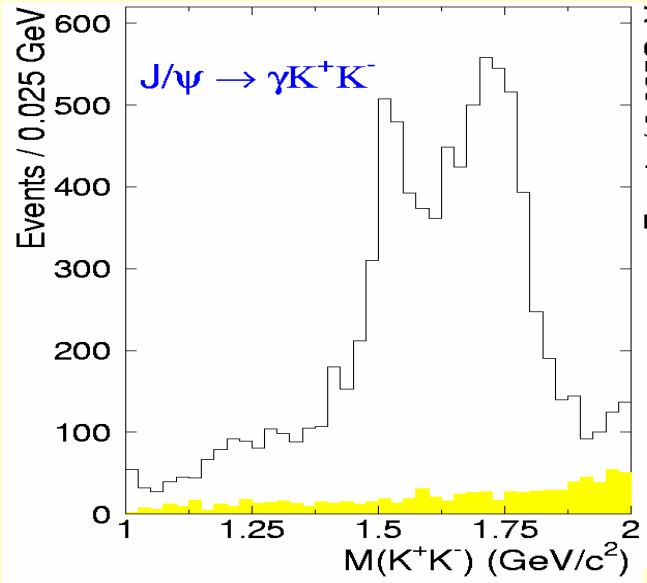
- Progress! Heavy onia spectroscopy is an active field, with many things mapped out
- Theory coming along
- Close data and theory cooperation in a new regime of precision is crucial
- More at “Workshop on Quarkonium”, September 20-22, 2003, Fermilab

Search for E1 transition between h_b and η_b



$B(\Upsilon'' \rightarrow h_b + (\pi^0 \text{ or } \pi^+ \pi^-)) \times B(h_b \rightarrow \gamma \eta_b)$
in units of 10^{-3} :

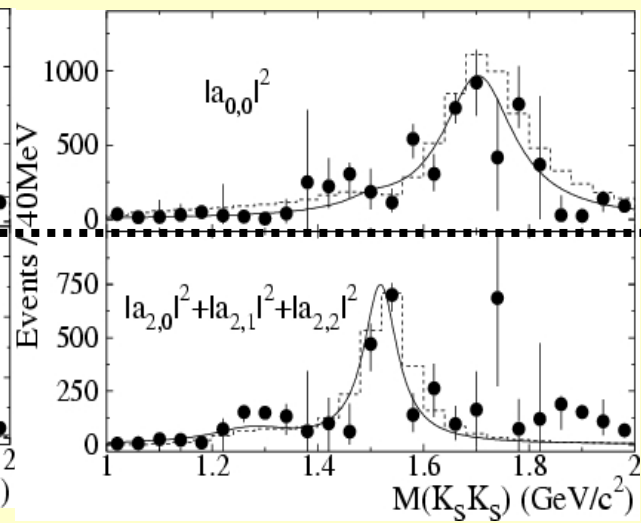
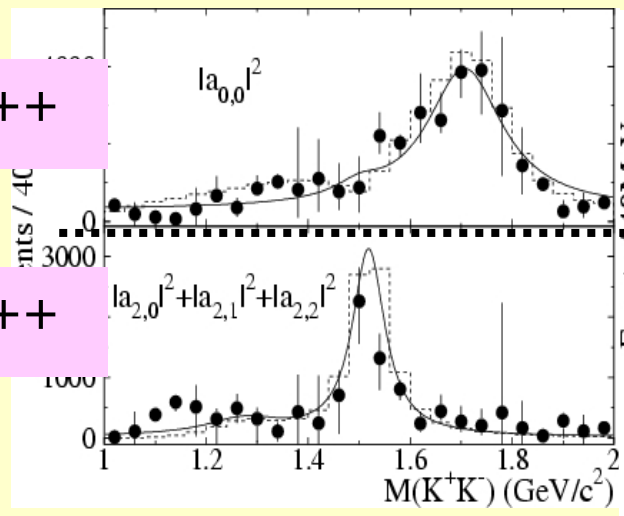




BES PWA findings in $J/\psi \rightarrow \gamma KK$

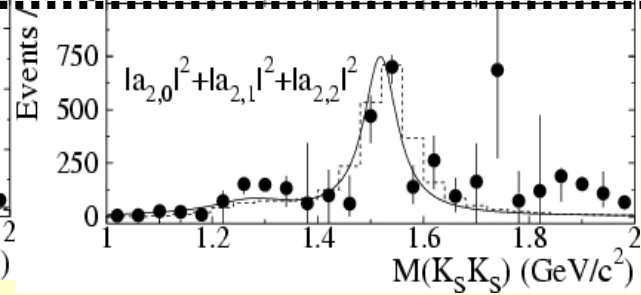
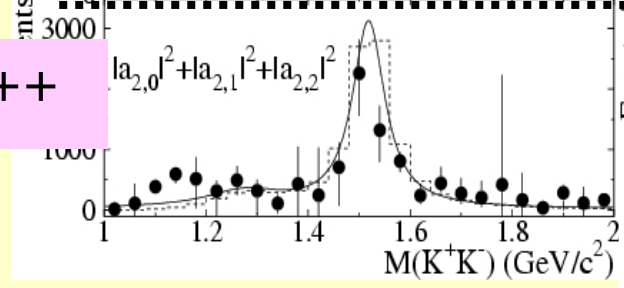
BES prelim, expect publication soon

0^{++}



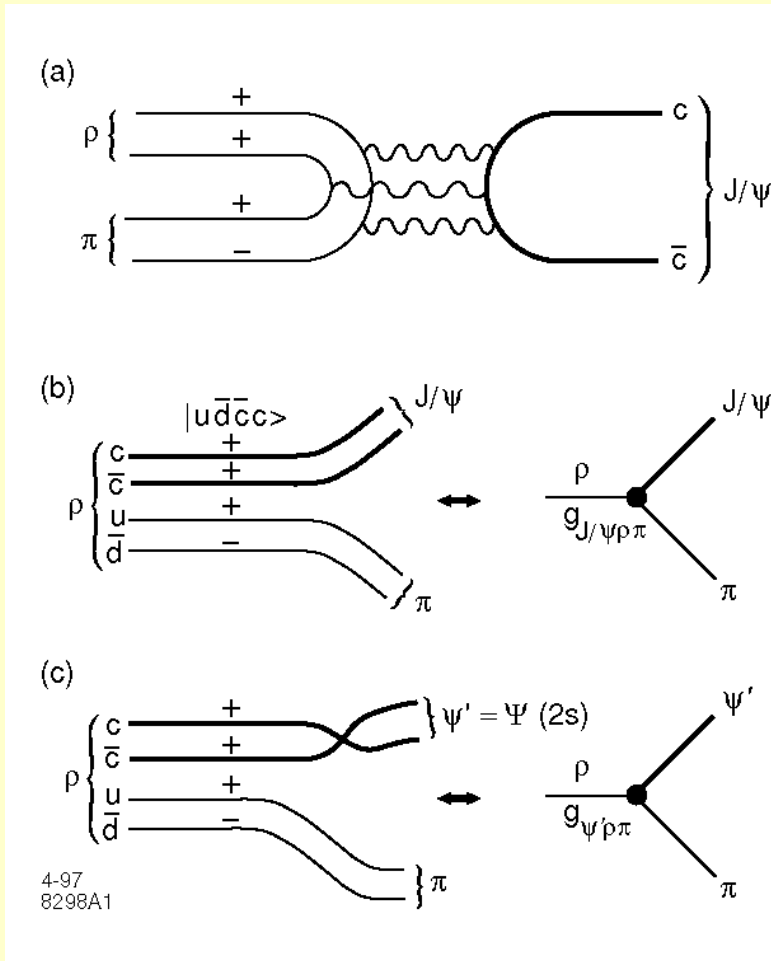
$m = 1518 \pm 6 \text{ MeV}$
 $\Gamma = 84^{+28}_{-24} \text{ MeV}$

2^{++}



$m = 1703^{+8}_{-10} \text{ MeV}$
 $\Gamma = 84^{+27}_{-22} \text{ MeV}$

Intrinsic Charm a la Brodsky and Lepage



DONE