CLEO $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ Results

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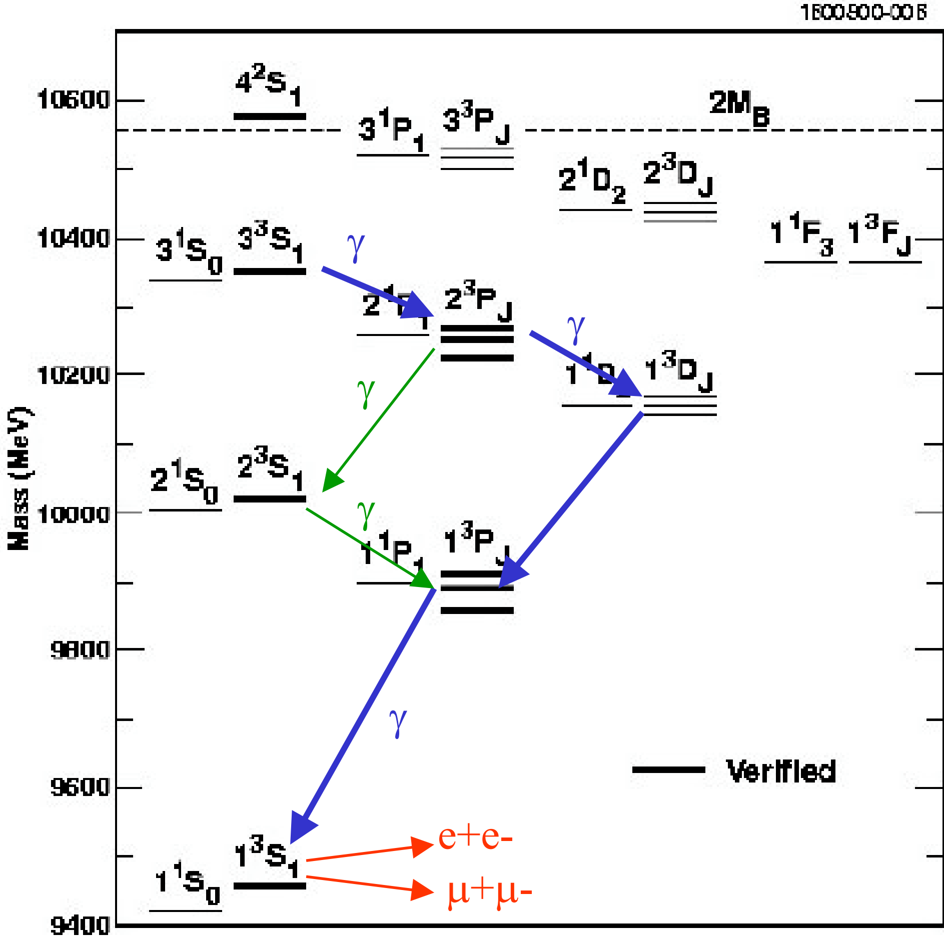
CLEO Collaboration

- 1st Observation of Υ**(**1D**)** States
- $\Upsilon(3S) \rightarrow \gamma\ \eta\_b$ Search
- $\Upsilon(1S) \rightarrow \eta'\ X$ Production
- Summary

Observation of Υ(1D) States

- bb states: ideal lab for LQCD + Strong interaction Effective Thy's
- Symmetric e+ e- collider @ $\sqrt{s}$ = Υ(3S)
- ∫ Ldt = 1.1 fb-1 ⇒ 4.7 x 10^6 Υ(3S) events
- CLEO-III detector: CsI calorimeter key
- Selection scheme:

Υ(3S)→γ χ_b(2P_J)
  └→ γ Υ(1D)
    └→ γ χ_b(1P_J)
      └→ γ Υ(1S)
        └→ ee, μμ



- Theory: O'all *Br* = 3.8 x 10^{-5}

S. Godfrey + J. Rosner, PRD64, (2001) 097501

W. Kwong + J. Rosner, PRD 38, (1988) 279

Observation of $\Upsilon(1D)$ States

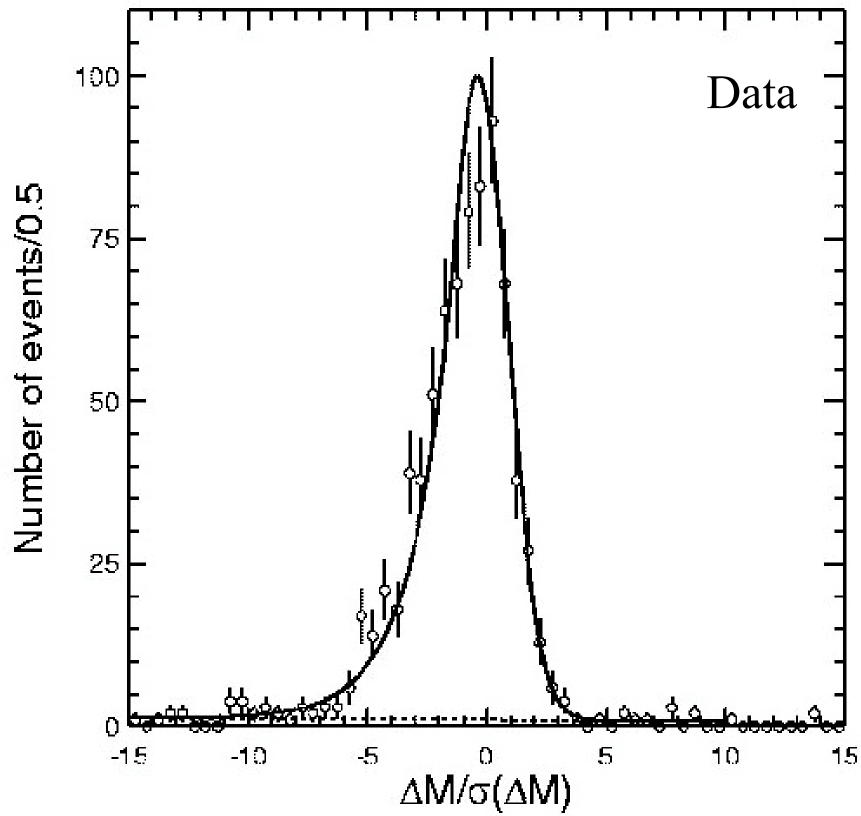
$\Upsilon(3S) \rightarrow \pi^0\pi^0\, \Upsilon(1S)$ Dominant BKG

$\gamma\gamma\ \gamma\gamma\ l^+l^-$ Check of Technique

Key Analysis Variables

$\chi^2\_\pi^0\pi^0$ built from both γ-pairs

$\Delta M = M(\text{ recoil } 4\gamma) - M\_\Upsilon(1S)$



Fit $\Delta M/\sigma(\Delta M)$ w/ MC shape

Yield ($\Upsilon(3S) \rightarrow \gamma\gamma\gamma\gamma\ l^+l^-$) : 737 ± 28

$\varepsilon(MC) = 13.6\%$

$Br(\Upsilon(3S) \rightarrow \pi^0\pi^0\, \Upsilon(1S)) * Br(\Upsilon(1S) \rightarrow l^+l^-)$

$= (5.67 \pm 0.22 \pm 0.25) \times 10^{-4}$

Preliminary

$Br(\Upsilon(3S) \rightarrow \pi^0\pi^0\, \Upsilon(1S)) = (2.33 \pm 0.09 \pm 0.16)\%$

v. CLEOII (2.03 ± 0.28 ± 0.19)%

CUSB (2.3 ± 0.4 ± 0.3)%

Υ(1D) cascade selection

χ^2 (M_ Υ(1D), J_2P, J_1P)

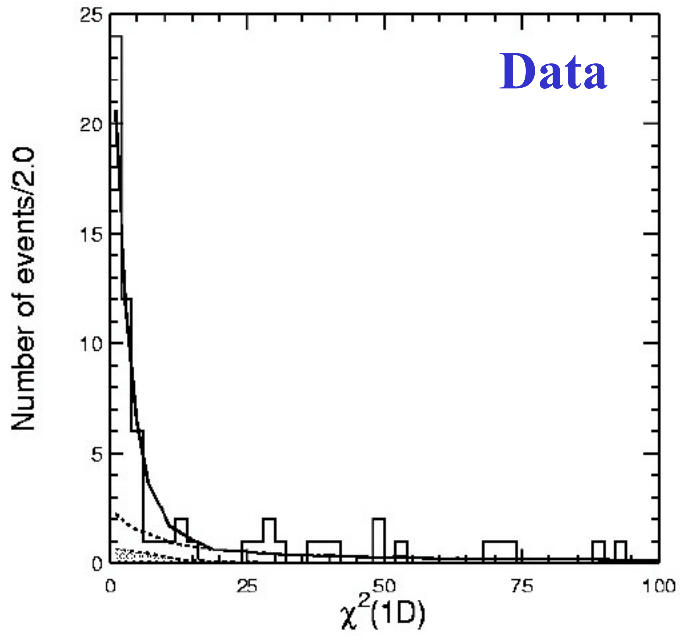
χ^2_$\pi^0\pi^0$ rejects Υ(3S) →$\pi^0\pi^0$ Υ(1S)

χ^2_{2S} rejects Υ(2S) cascades

$\gamma\gamma\ \gamma\gamma\ l^+l^-$ final state:

Υ(1D) yield = 40.7 ± 6.8 evts (9.7σ)

BKG: 9.5 - 14 % (χ^2_{1D} < 10)



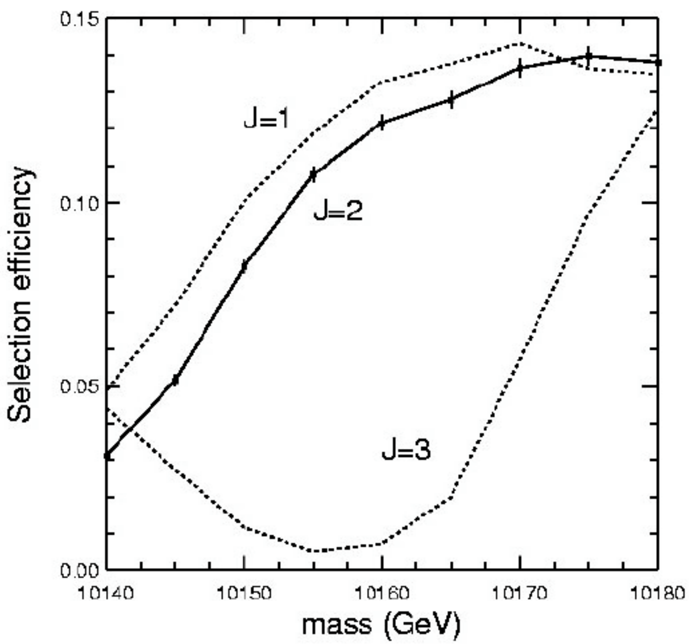
Υ(1D) cascade signal = F(M_Υ(1D), J_1D)

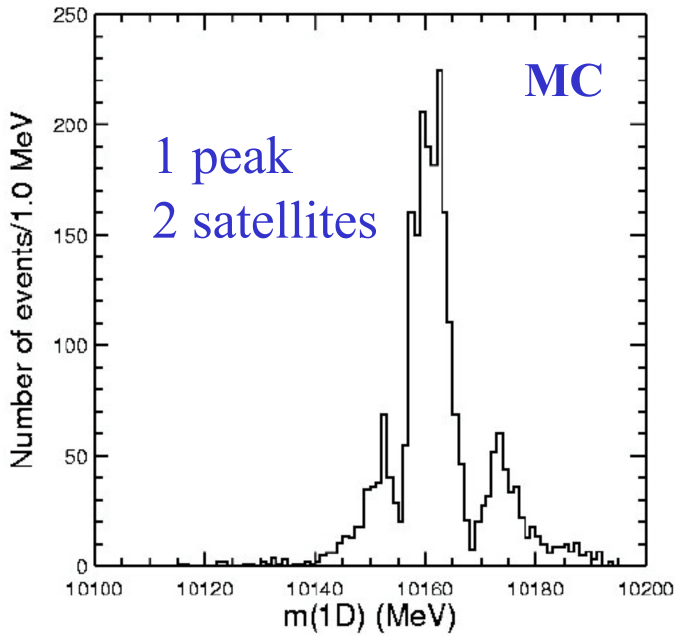
Br (J= 1) = 0.4 x10^{-5}

Br (J= 3) = 0.8 x10^{-5}

Br (J= 2) = 2.6 x10^{-5}

[S. Godfrey + J.L. Rosner, PRD64 (2001) 097501]





2-Peak Fit

- M_low = 10161.2±0.7 MeV

  $N = 27.8^{+6.8}_{-6.0}$ events

- M_high = 10174.2±1.3 MeV

  $N = 12.0^{+5.3}_{-4.6}$ events

- 58% C.L.

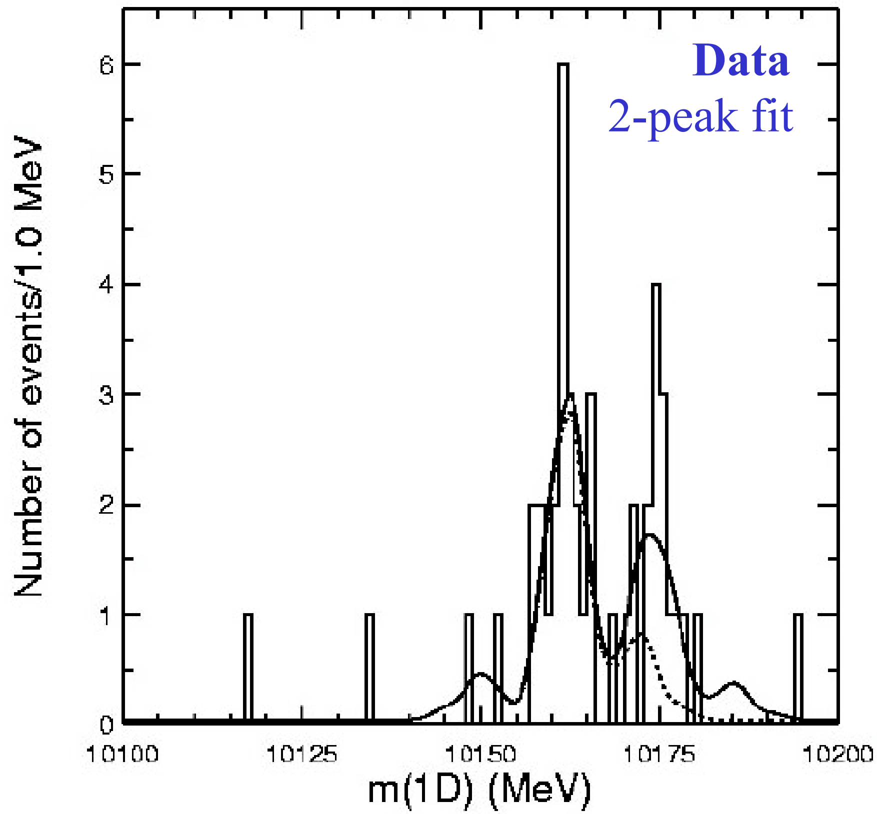
1-Peak Fit

- M_low = 10162.0±0.5 MeV

  $N = 38.6^{+6.8}_{-6.2}$ events

- 43% C.L.

Fit to E_cm – M _recoil(2γ)



Preliminary

M_ϒ(1D) = 10162.2 ±1.6 MeV (6.8σ)

J_1D = 2 favored, J_1D = 1 not excluded

Br (ϒ(3S) 5-stage cascade via ϒ(1D)) = $(3.3 \pm 0.6 \pm 0.5) \times 10^{-5}$

$\eta_b(1S)$ Search in Radiative $\Upsilon(3S)$ Decays

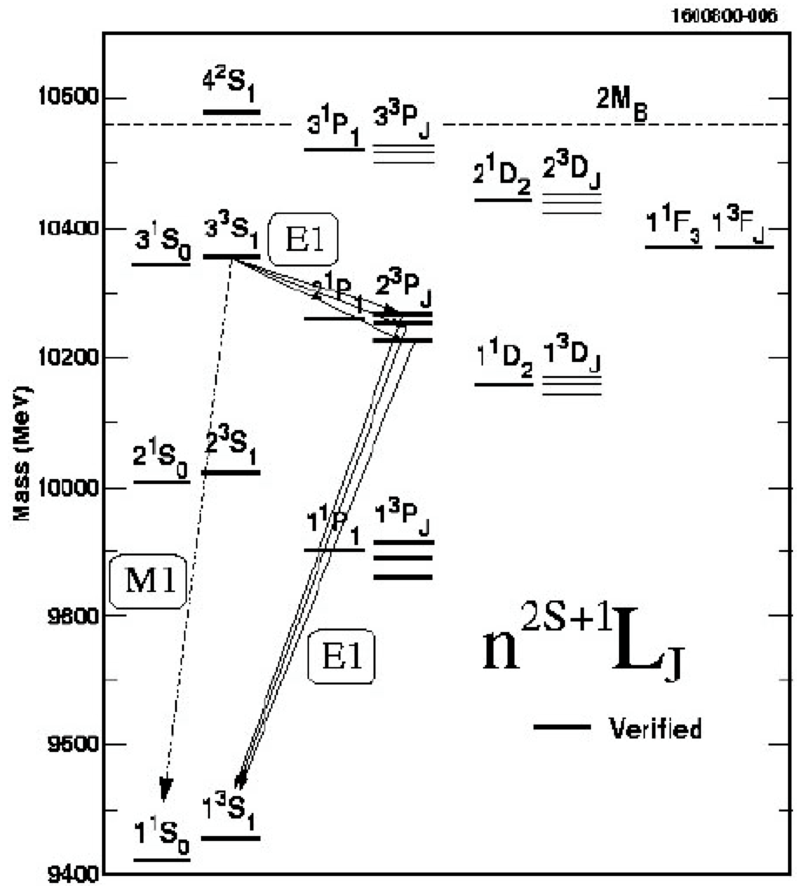
- No Spin = 0 $b\bar{b}$ state yet observed
  E.g., $\eta_b(1S)$ ($b\bar{b}$ ground state)

- Υ(Triplet) $\to$ η_b(Singlet) via M1 transitions

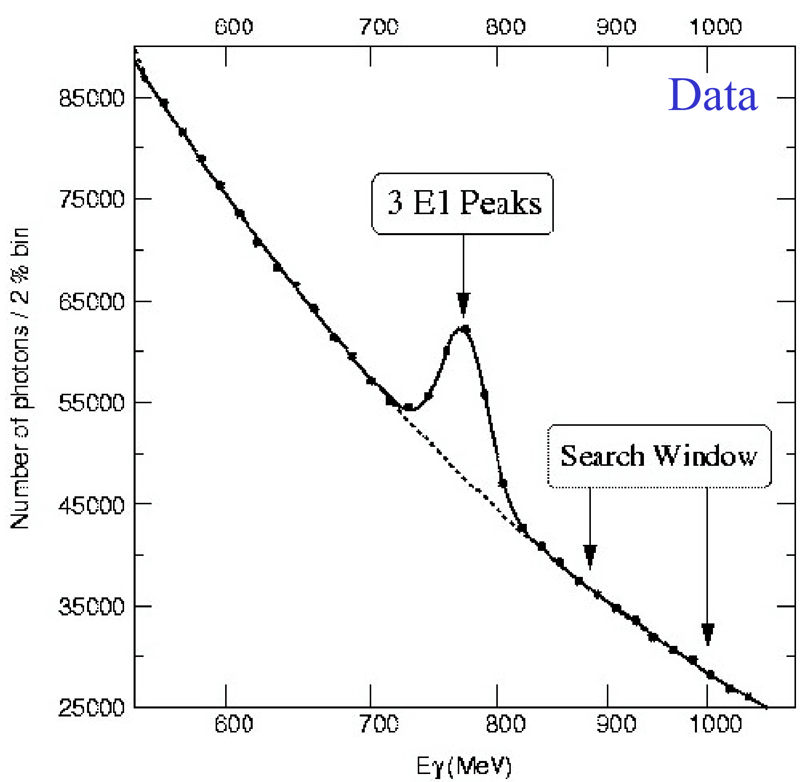
  $$\Gamma[\Upsilon(nS) \to \gamma\, \eta_b(n'S)] = \frac{4\alpha q_b^2 I^2 E_\gamma^3}{3 m_b^2}$$

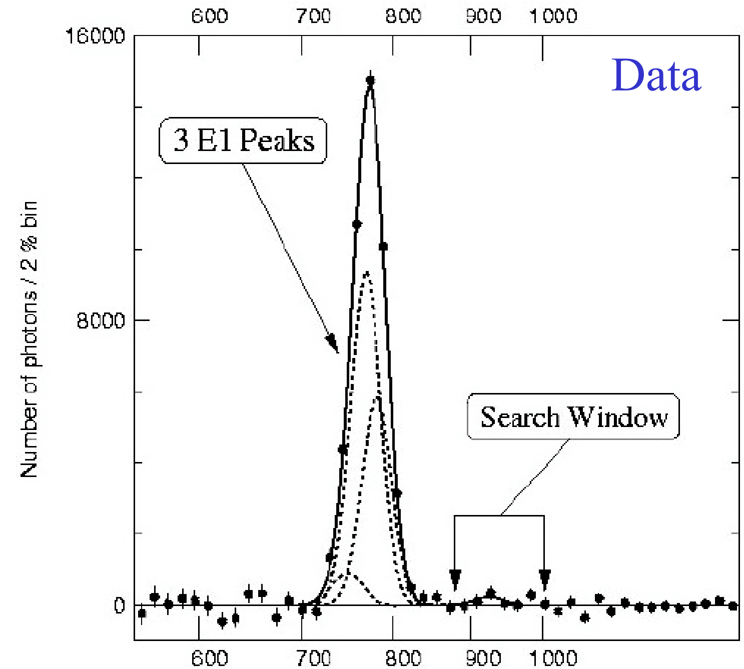
- Use n' $\neq$ n M1 transitions
  Avoid $\Upsilon(nS) \to \gamma\, \eta_b(nS)$, E_γ = 100 MeV

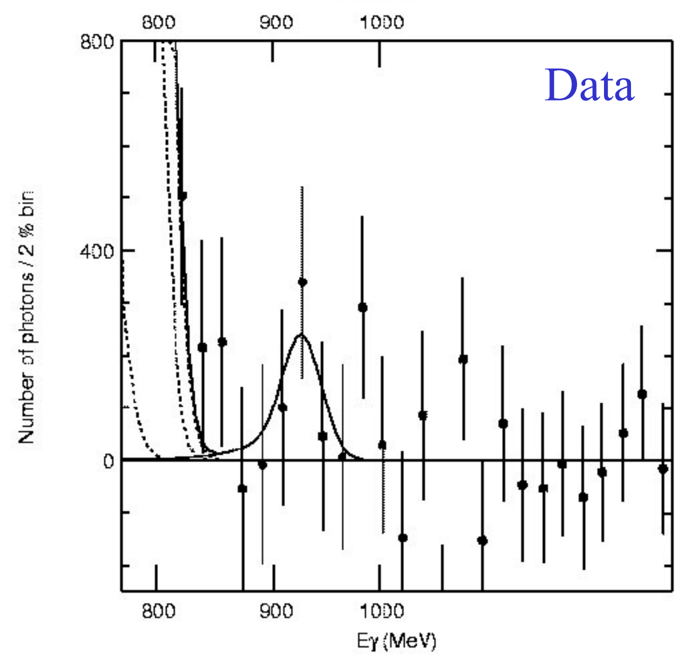
- Tune search w/ E1 decay
  $\chi_b(2P_J) \to \gamma\, \Upsilon(1S)$, E_γ ~ 770 MeV
  Use isolated, "good barrel" γ's: π^0 rejection



$\eta_b(1S)$ Search in Radiative $\Upsilon(3S)$ Decays



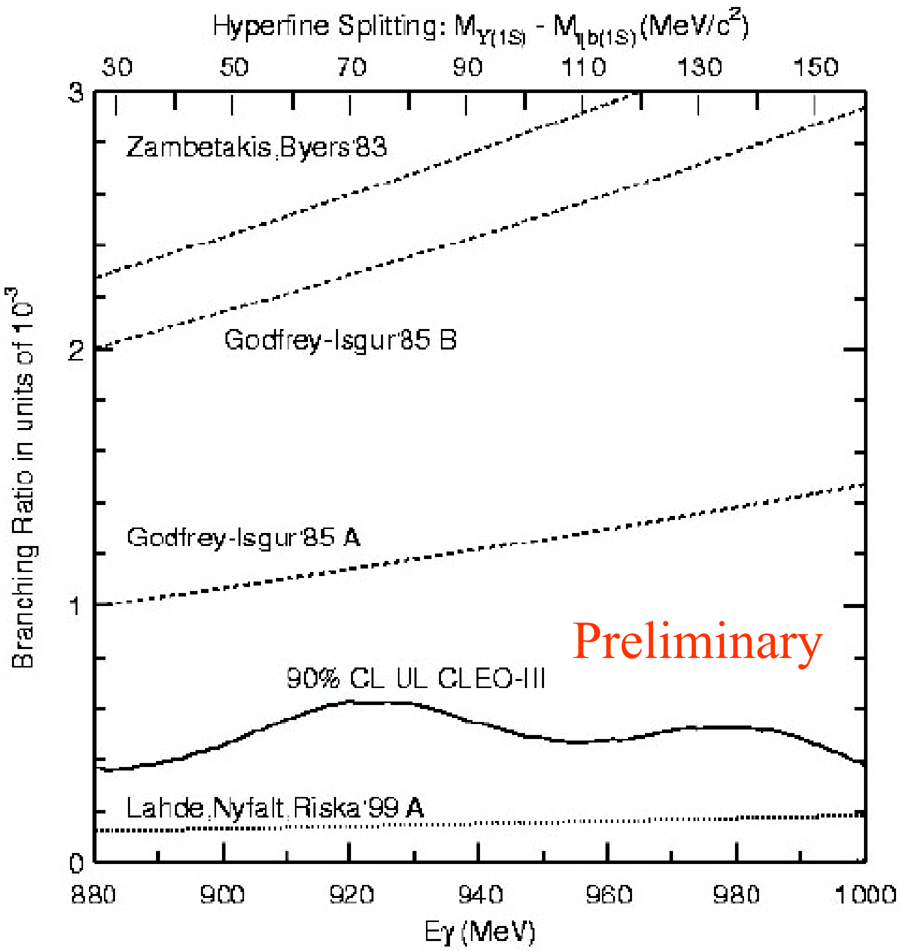




- Multiple fits w/ 880 MeV < E_γ < 1000 MeV
- Max yield = 698 ± 463 evts (1.5σ)

∴ NO $\eta_b(1S)$ seen

$\eta_b(1S)$ Search in Radiative $\Upsilon(3S)$ Decays

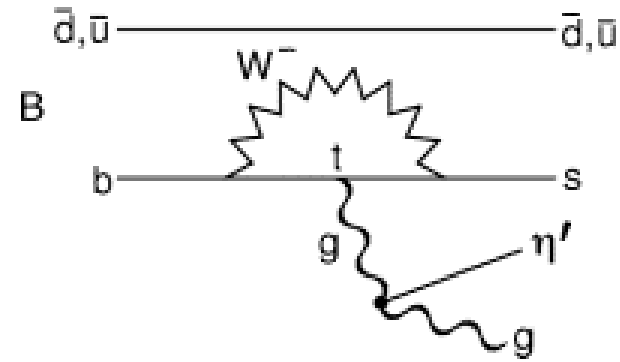


- Selection ε from MC (w/ M_ η_b(1S) = 9.4 GeV)
- 90% C.L. upper limit via PDG
- Some phenomenological models excluded

ICHEP02 ABS947

$\Upsilon(1S) \to \eta' X$

• "High" $Br(B \to \eta' X_s) = (6.2 \pm 1.6 \pm 1.3) \times 10^{-4}$, $2 \le P\_\eta' \le 2.7$ GeV
[CLEO, PRL **81** (1998) 1786]
[BABAR, hep-ex/0109034]

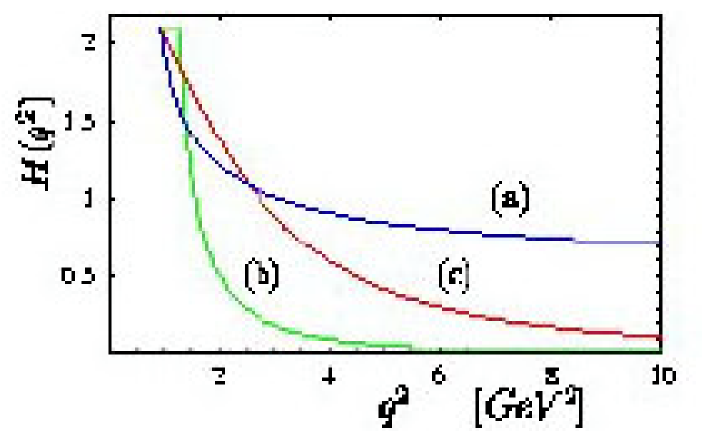


• $b \to s(g^* \to g\,\eta')$

[D. Atwood + A.Soni, PLB **405** (1997) 150]
[W.S. Hou + B. Tseng, PRL **80** (1998) 434]
[A. Kagan + A. Petrov, hep-ph/9707354]

$H(q^2)\varepsilon_{\alpha\beta\mu\nu}q^\alpha k^\beta \varepsilon^\mu \varepsilon^\nu$ [A. Kagan hep-ph/0201313]

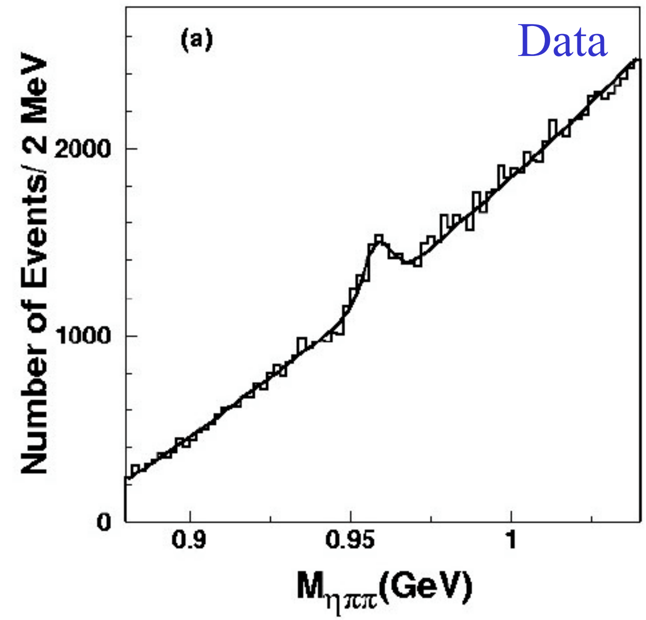
Probe ($b \to sg\,\eta'$) w/ fast η': $\Upsilon(1S) \to ggg \to \eta' X$



• Models assume <u>only</u> $\Upsilon(1S) \to ggg \to \eta' X$
Must correct for $\Upsilon(1S) \to qq \to \eta' X$
$e^+e^- \to qq \to \eta' X$

$\Upsilon(1S) \to \eta' X$

- $\int Ldt$ = 80 pb-1 @ $\sqrt{s} = \Upsilon(1S) \Rightarrow 1.86 \times 10^6\ \Upsilon(1S)$ events
- $\int Ldt$ = 1193 pb-1 @ $\sqrt{s} = \Upsilon(4S)|_-$ (continuum)

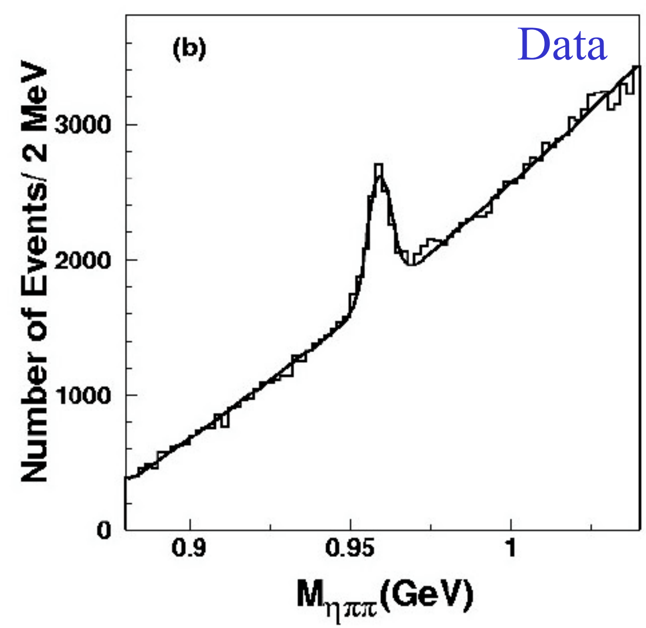


- $\eta' \to \eta\pi^+\pi^-$
  - $\to \gamma\gamma$

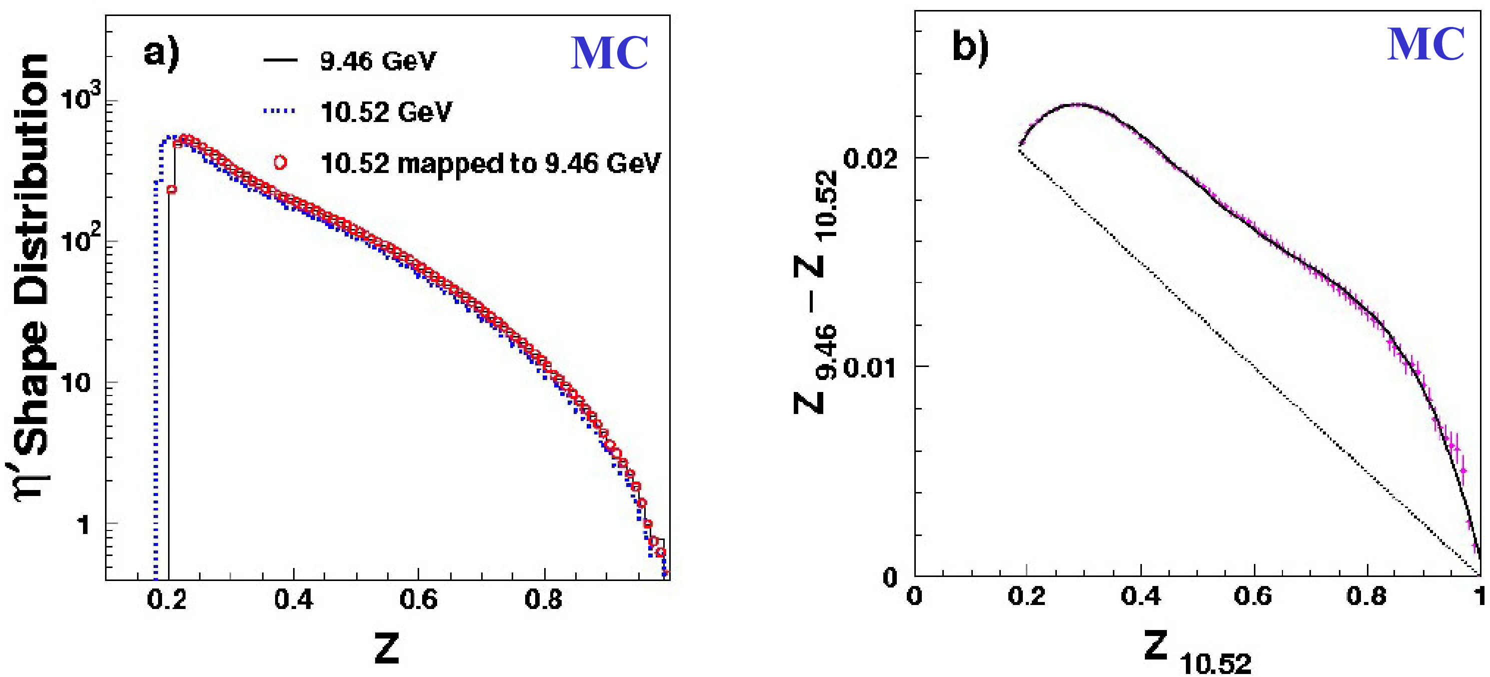
π^0 rejection for Z < 0.5

$Z = E\_\eta' / E\_beam = 2E\_\eta'/M\_\Upsilon(1S)$

η' recon eff = 10 - 25 %



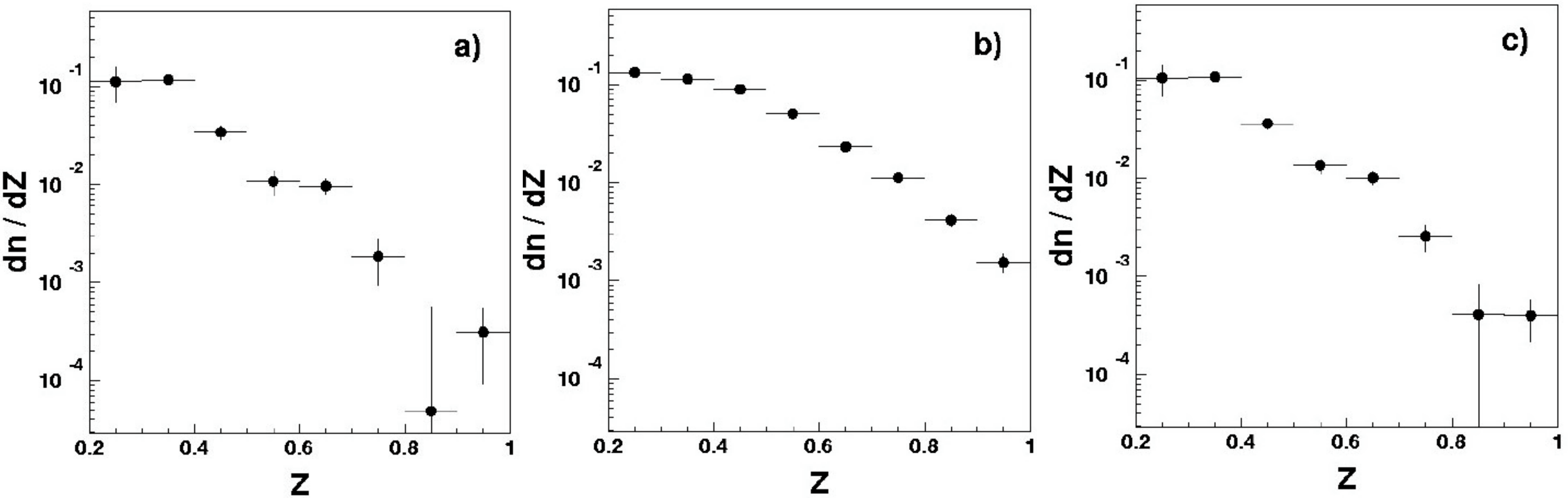
$\Upsilon(1S) \to \eta' X$



- Use e+e- → qq @ √s ≈ ϒ(4S)

  To estimate e+e- → qq @ √s = ϒ(1S)

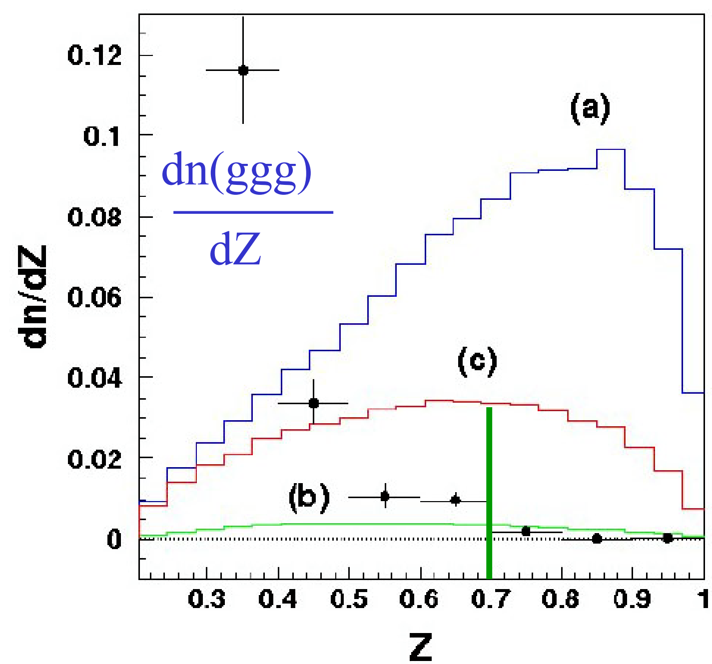
$$\int_0^{Z'_{10.52}} P_{10.52}(z)\, dz = \int_0^{Z'_{9.48}} P_{9.48}(z)\, dz$$



$$\frac{dn(ggg)}{dZ} = \frac{d\,Br(\Upsilon\,(1S) \rightarrow ggg \rightarrow \eta'\,X)}{dZ \text{ x } Br(\Upsilon\,(1S) \rightarrow ggg\,)}$$

$$\frac{dn(qq)}{dZ} = \frac{d\,Br(\Upsilon\,1S) \rightarrow qq \rightarrow \eta'\,X)}{dZ \text{ x } Br(\Upsilon\,1S) \rightarrow qq\,)}$$

$$\frac{dn(1S)}{dZ} = \frac{d\,Br(\Upsilon\,1S) \rightarrow \eta'\,X)}{dZ}$$



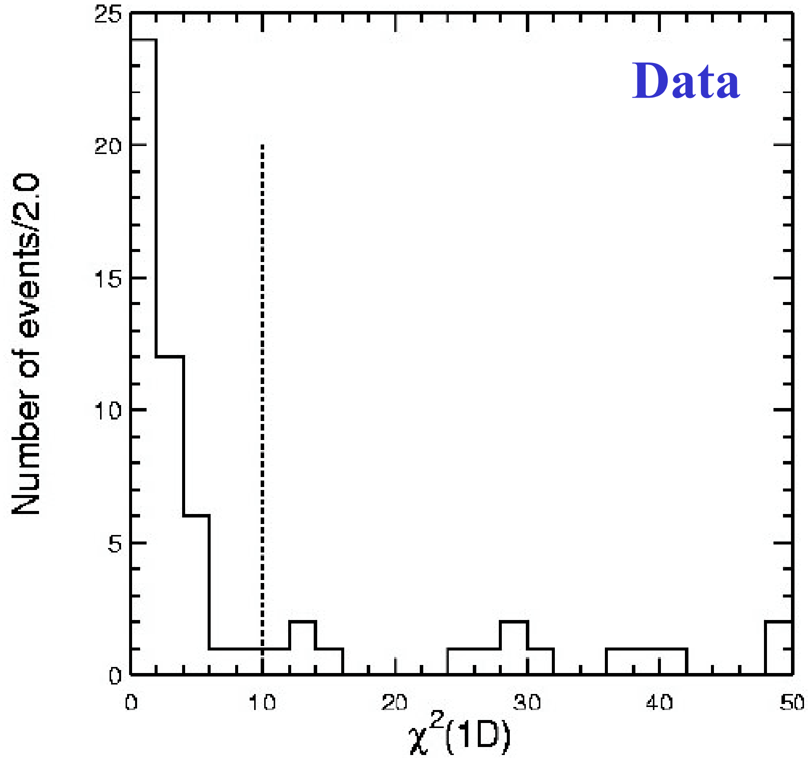
NO enhanced η′ g*g coupling seen @ large η′ energies

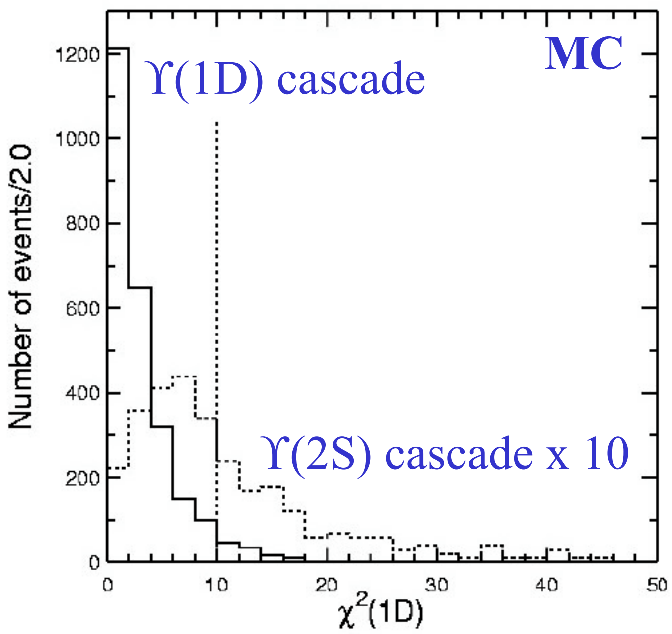
hep-ex/0211029 v2

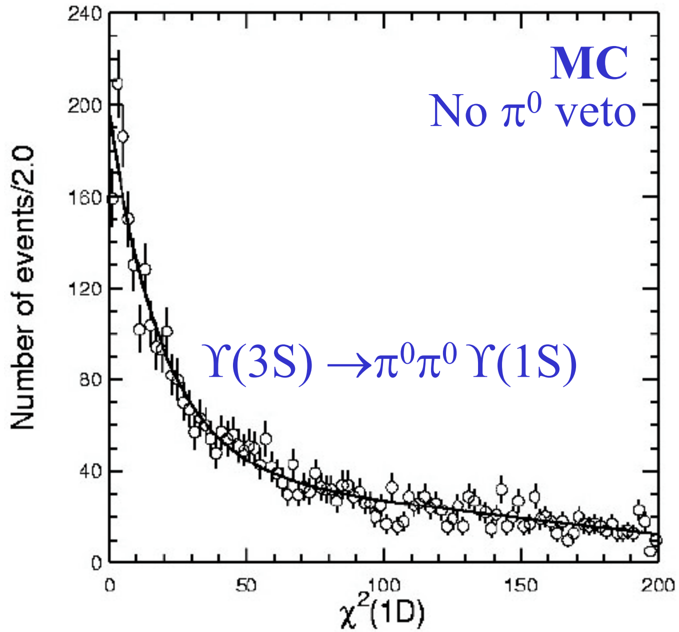
Summary

- 1st Observation of Υ (1D) States
- No $\eta_b(1S)$ seen
- No large anomalous $g^* g \eta'$ coupling in Υ (1S) $\rightarrow \eta' X$ decays

Back-Up Slides


Data
Number of events/2.0
χ^2(1D)
0
5
10
15
20
25
0
10
20
30
40
50


MC
ϒ(1D) cascade
ϒ(2S) cascade x 10
Number of events/2.0
1200
1000
800
600
400
200
0
0
10
20
30
40
50
χ²(1D)


MC
No π^0 veto
$\Upsilon(3S) \rightarrow \pi^0\pi^0\,\Upsilon(1S)$
Number of events/2.0
χ^2(1D)
240
200
160
120
80
40
0
0
50
100
150
200