Evidence for η_c' production in $\gamma\gamma$ Fusion at CLEO

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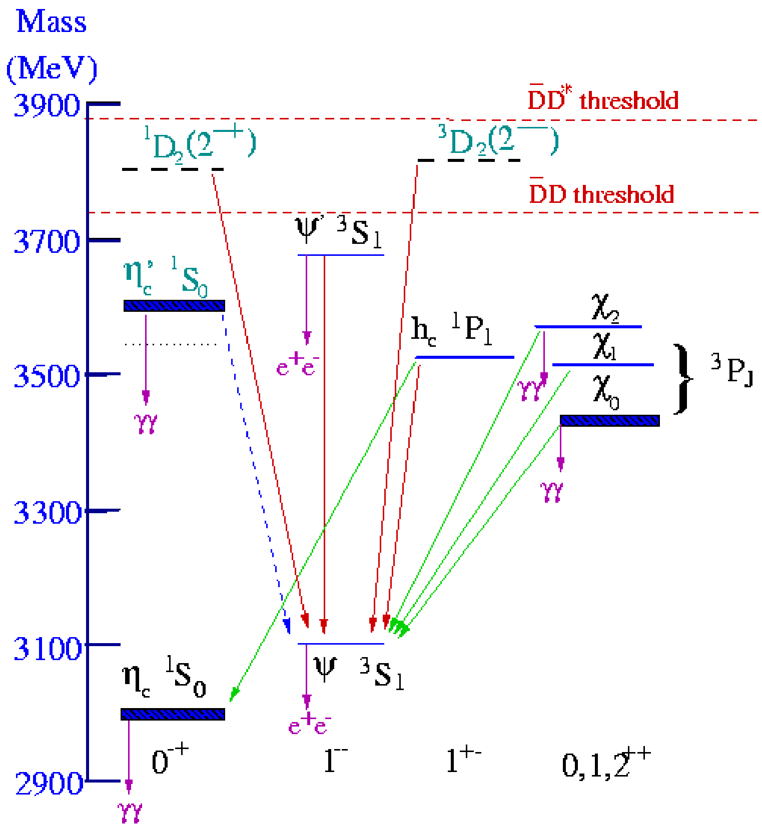
For the CLEO Collaboration

The Importance of $\eta_c'(2^1S_0)$



- The existing experimental knowledge of the hyperfine splitting is $\Delta M \equiv M(J/\psi) - M(\eta_c) = 117 \pm 2$ MeV.

- $\Delta M \equiv M(\psi') - M(\eta_c') =$? - important for understanding of the spin-spin interaction in the confinement region.

- Theoretical predictions based on potential model calculations are
  - $M(\eta_c') \sim$ 3594 - 3629 MeV
  - $\Gamma_{\gamma\gamma}(\eta_c')/\Gamma_{\gamma\gamma}(\eta_c) \simeq$0.70

Current Experimental Status of $\eta_c'(2^1S_0)$

- Crystal Ball Collaboration:

$$e^+e^- \to \psi' \to \gamma X,$$

$M(\eta_c')$=3594 $\pm$ 5 MeV, $\Gamma(\eta_c')$ <8 MeV, PRL 48(1982)70.

<u>Unsuccessful searches</u>

- E760-E835 Fermilab Collaboration

$$\bar{p}p \to \eta_c' \to \gamma\gamma$$

PRD 52(1995)4839,
PRD 64(2001)052003

- DELPHI Collaboration

$$\gamma\gamma \to \eta_c' \to hadrons$$

PL B441(1998)479

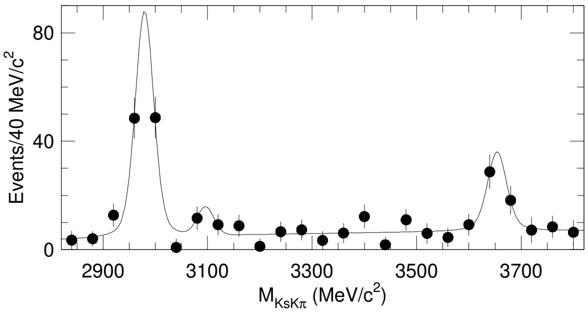
- L3 Collaboration

$$\gamma\gamma \to \eta_c' \to hadrons$$

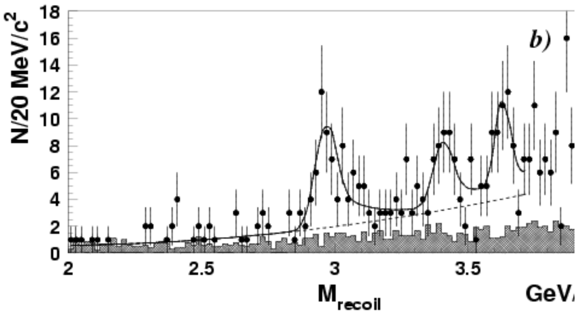
PL B461(1999)155

- Belle Collaboration

$B \to K(K_s K^{\mp}\pi^{\pm})$
PRL 89(2002)102001



$e^+e^- \to J/\psi(X)$
PRL 89(2002)142001



$M(\eta_c')$=3654 ± 6 ± 8 MeV
$\Gamma(\eta_c') <$ 55 MeV (90% CL)
$N(\eta_c')$= 39 ± 11 counts
signif. $>$ 6 σ

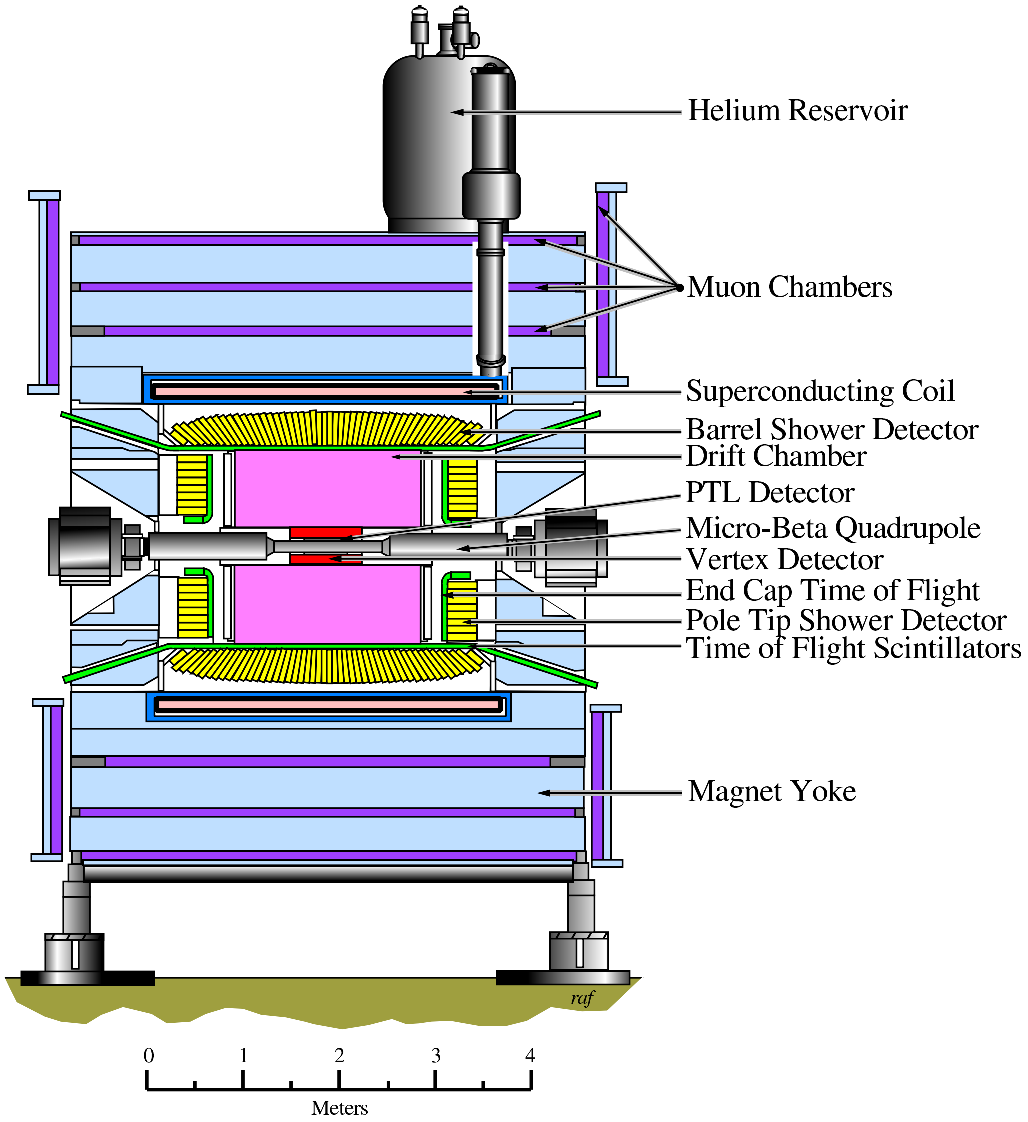
$M(\eta_c')$=3622 ± 12 MeV

$N(\eta_c')$= 42^{+15}_{-13} counts
signif. = 3.4 σ

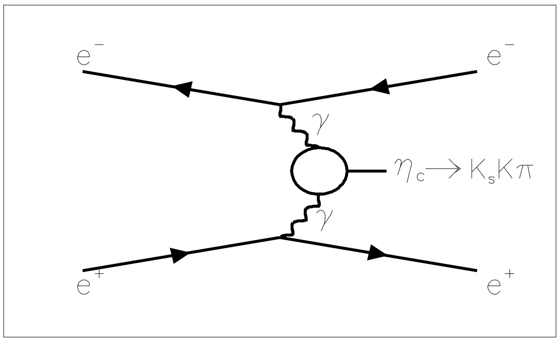
– $M(\eta_c')$= 3654±6±8 MeV is 60 MeV larger than the Crystal Ball result.

– $\Delta M(\psi' - \eta_c')$=32 MeV is much smaller than expected on theoretical grounds.

CLEOII/II.V Detector



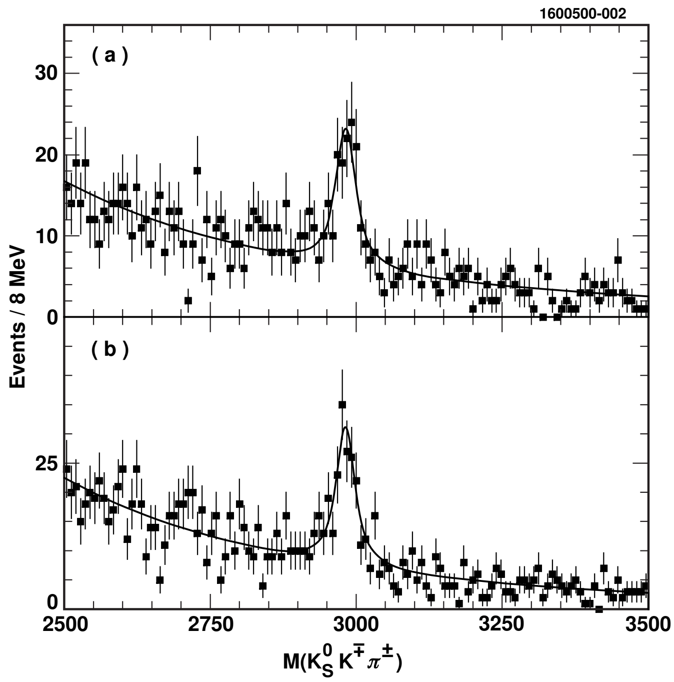
η_c Results from CLEOII/II.V Data



$$e^+e^- \rightarrow e^+e^-(\gamma\gamma) \rightarrow e^+e^-(\eta_c) \rightarrow e^+e^-(K_s^0 K^\pm \pi^\mp)$$

13.4 fb^{-1} CLEOII/II.V data taken at Υ(4S) and its vicinity.

PRL 85(2000)3096



CLEOII

CLEOII.V

We extended the analysis in high $K_s K \pi$ mass region to search for η_c' signal in the same reaction and data.

Event Selection Criteria

$$\gamma\gamma \to \eta_c' \to K_s^0 K^\pm \pi^\mp$$

– Exactly four reconstructed charged tracks in the detector

– One $K_s \to \pi^+\pi^-$ candidate (standard K_s selection criteria)

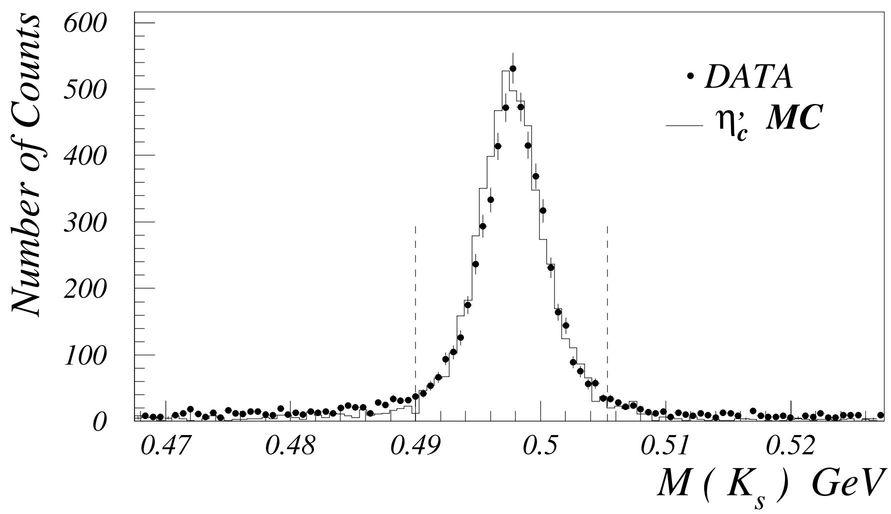
– Transverse momentum of the system below 600 MeV

– Amount of unmatched energy, detected in calorimeter below 200 MeV

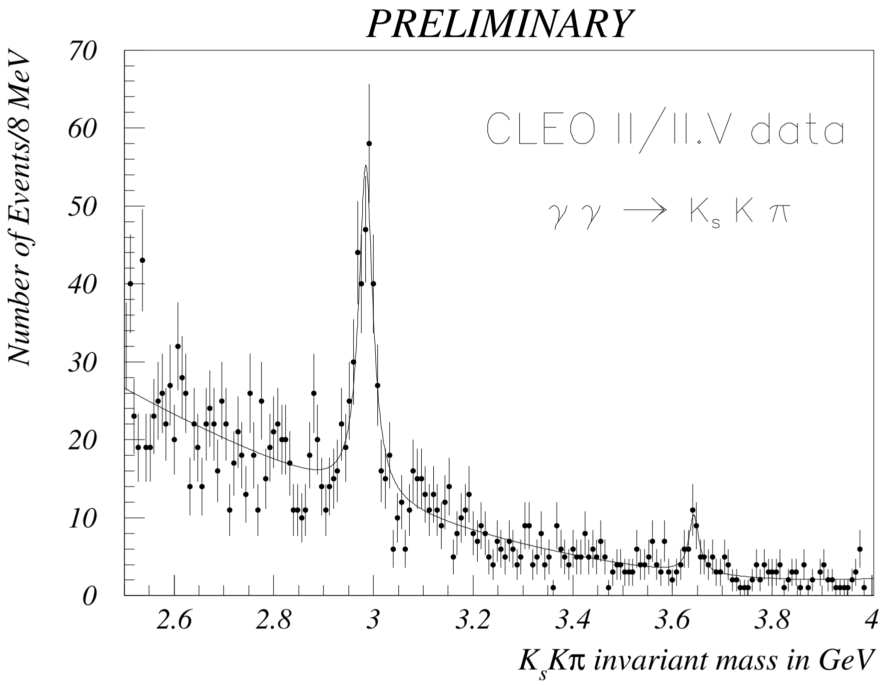
– $|\ cos(\theta)\ |$<0.91 for charged π and K

– Charged particle identification using dE/dx and TOF information (efficiencies = 89.9% and 92.5% from η_c and η_c' signal MC)

The total efficiencies:
10.0% from η_c signal MC
13.8% from η_c' signal MC



η_c' Results from CLEOII/II.V Data



Fit - second order polynomial background and two Breit-Wigners.

- The preliminary results are

N(η_c) = 287 ± 28 N(η_c') = $36\ ^{+15}_{-11}$

M(η_c) = 2984.7 ± 2.1 MeV M(η_c') = 3642.7 ± 4.0 MeV

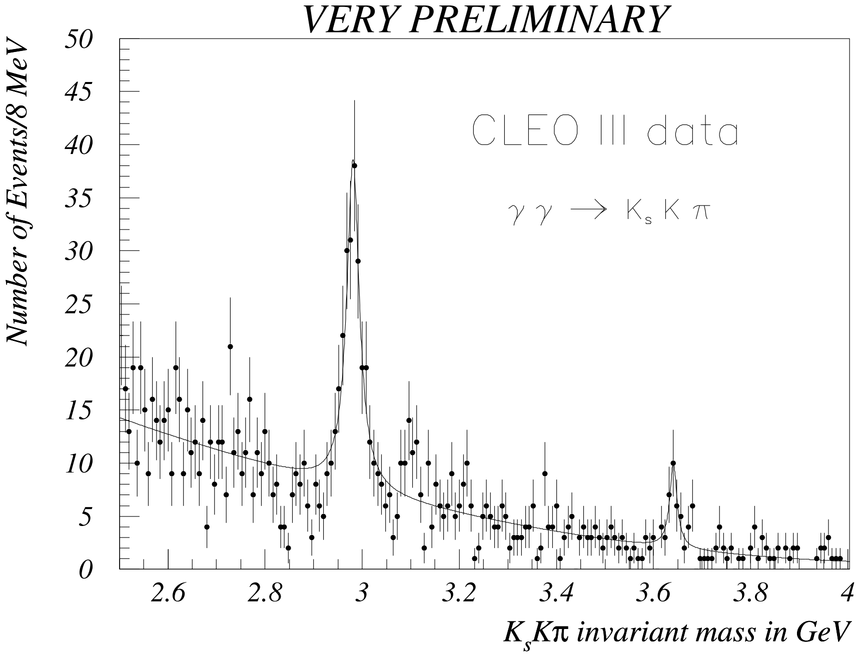
- Significance of the η_c' signal is: $\sigma = \sqrt{2\ln(L_{max}/L_0)} = 5.0$

The probability, that the background can fluctuate to produce the signal like structure, without prior knowledge of mass and width, corresponds to the significance of η_c' signal at $\geq 4\sigma$ level.

- $R(\eta_c'/\eta_c) \equiv \dfrac{\Gamma_{\gamma\gamma}(\eta_c')\times B(\eta_c'\to K_sK\pi)}{\Gamma_{\gamma\gamma}(\eta_c)\times B(\eta_c\to K_sK\pi)} = 0.17\pm0.06(\text{stat})$

η_c' Results from CLEOIII Data

Modified CLEOIII detector contains the new Drift Chamber and RICH detector, which provide the superior particle identification capabilities. 9.2 fb^{-1} data have been analyzed.



- Very preliminary results from CLEOIII data confirm the evidence of η_c' production at a similar significance level and mass value.

- $N(\eta_c) = 191 \pm 22$ $\quad N(\eta_c') = 29^{+9}_{-8}$
  $M(\eta_c) = 2981.1 \pm 2.2$ MeV $\quad M(\eta_c') = 3640.6 \pm 3.3$ MeV

- $$R(\eta_c'/\eta_c) \equiv \frac{\Gamma_{\gamma\gamma}(\eta_c')\times B(\eta_c'\to K_s K\pi)}{\Gamma_{\gamma\gamma}(\eta_c)\times B(\eta_c\to K_s K\pi)} = 0.24 \pm 0.06(\mathrm{stat})$$

- Transverse momentum distributions of $K_s K\pi$ system for CLEOII/II.V and CLEOIII data, confirm that the enhancement that we observe is due to two-photon fusion.

Summary

At CLEOII/II.V (13.4 fb^{-1}) and CLEOIII (9.2 fb^{-1}) data we have searched for η_c' in the reaction $\gamma\gamma \to \eta_c' \to K_s K^{\pm}\pi^{\mp}$.
The PRELIMINARY results of our analysis can be summarized as follows:

- In the $K_s^0 K^{\pm}\pi^{\mp}$ invariant mass plot we see an excess of events at mass of $\sim$3640 MeV with the significance level of over 4σ from CLEOII/II.V data. The CLEOIII data confirm this observation with the similar level of significance. We attribute this excess to the excitation of the η_c' resonance.
- The combined value of η_c' mass from CLEOII/II.V and CLEOIII data is

$$M(\eta_c') = 3642 \pm 3(\text{stat}) \pm 4(\text{syst}) \text{ MeV},$$

consequently

$$\Delta M \equiv M(\psi') - M(\eta_c') = 44 \pm 3(\text{stat}) \pm 4(\text{syst}) \text{ MeV}.$$

- We also find that the combined value from CLEOII/II.V and CLEOIII

$$R(\eta_c'/\eta_c) \equiv \frac{\Gamma_{\gamma\gamma}(\eta_c') \times B(\eta_c' \to K_s K\pi)}{\Gamma_{\gamma\gamma}(\eta_c) \times B(\eta_c \to K_s K\pi)} = 0.21 \pm 0.04(stat) \pm ?(syst) \ .$$

ΔM and $R(\eta_c'/\eta_c)$ are smaller than most current theoretical predictions and should lead to new insight into spin–spin contribution of the confinement part of the $q\bar{q}$ potential, and the effect of coupling with pseudoscalar and vector states above the $D\bar{D}$ threshold.