Evidence for $\eta_c \to \gamma\gamma$ and Measurement of $J/\psi \to 3\gamma$

Selected highlights

Liu Kai

Introduction: physics picture

- **Decays of positronium(e+ e- system) to more than one photon are ideal enviroment for testing the QED**
  - Leptons (e+e-) only interact through electromagnetic interaction
- **The analogous processes in charmonia act as a prob of the strong interaction.**
  - in the quark-antiquark bond state, c/cbar interact with each other through electromagnetic and strong interactions both.

$$\mathcal{R} \equiv \frac{\mathcal{B}(J/\psi \to 3\gamma)}{\mathcal{B}(J/\psi \to e^+e^-)} = \frac{64(\pi^2 - 9)}{243\pi}\alpha(1 - 7.3\frac{\alpha_s(r)}{\pi})$$

Introduction: experimental status

- J/psi --> 3 gam process is firstly reported by CLEO.
- the value of *R* disagrees with the theoritical prediction
- Eta_c --> gam gam process is mainly done by the two-photon fusion process, suffering low statistics

Event Selections

- To reconstruct psi(2S) candidates from pi+ pi- 3gam final states:

The best $\psi(2S)$ candidate among all combinations of $\pi^+\pi^-\gamma\gamma\gamma$ in each event is determined by:

1. number of photons: $3 \leq N_{photon} \leq 7$,
2. number of charged tracks: $N_{charged-track} = 2$,
3. the recoiling mass against $\pi^+\pi^-$: $2.9\text{GeV} < M^{\pi^+\pi^-}_{\text{recoil}} < 3.3\text{GeV}$,
4. $\chi^2_{4C} < 200$, which implies a successful vertex fit,
5. the smallest χ^2_{4C}.

Background study:
mass spectrum of two photons

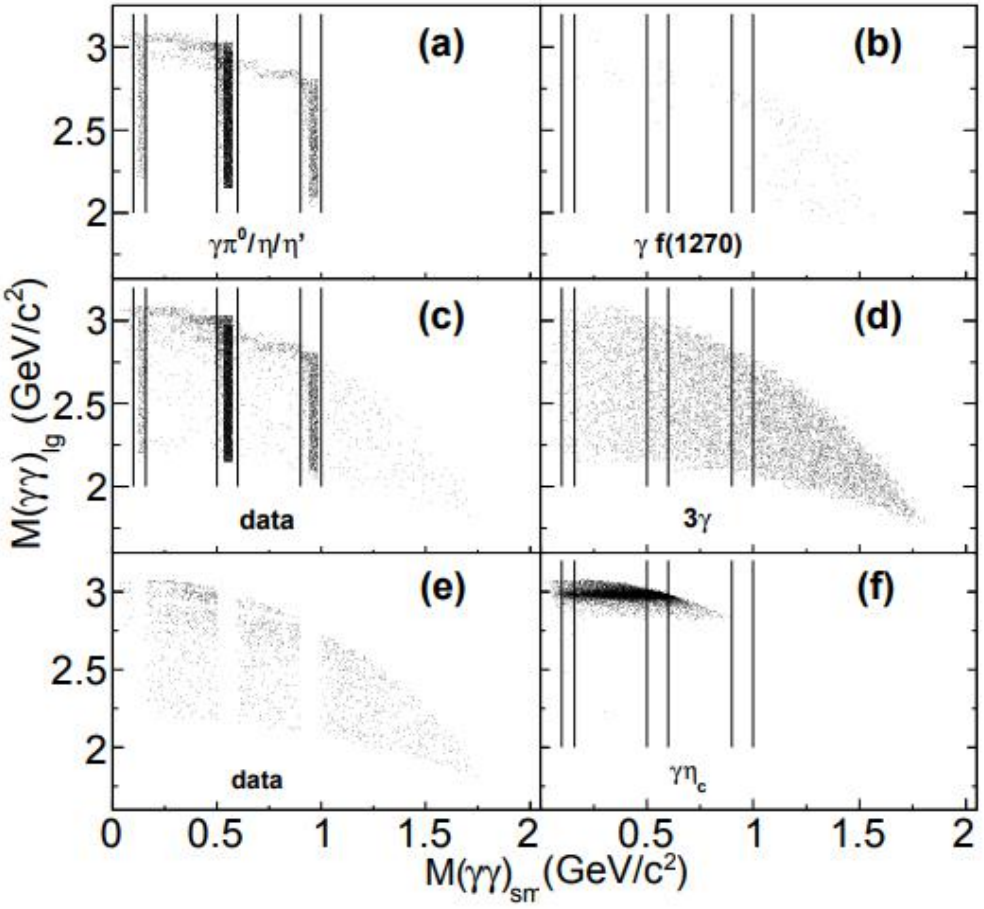
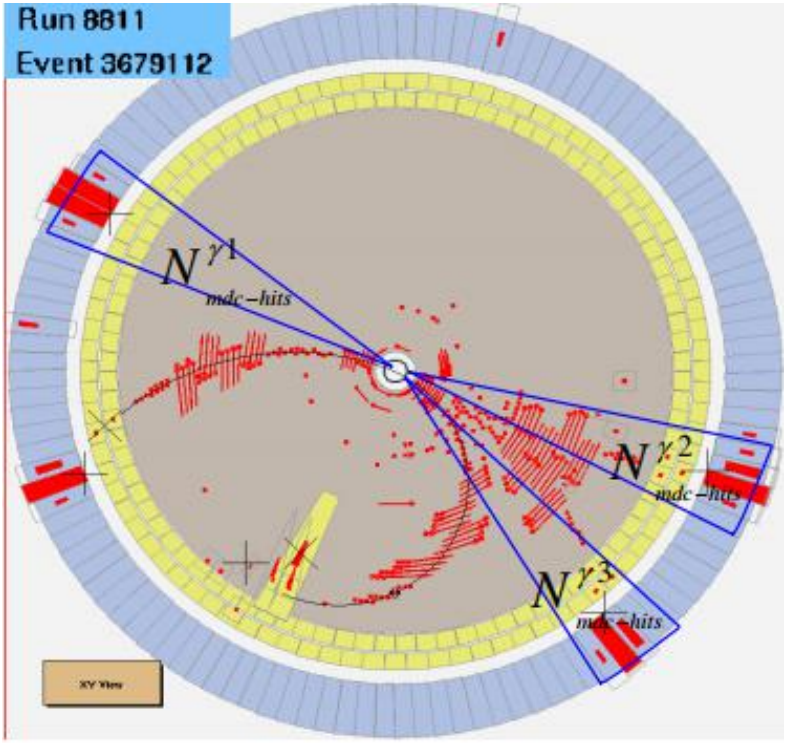


Figure 1: Scatter plots of $M(\gamma\gamma)_{\rm lg}$ versus $M(\gamma\gamma)_{\rm sm}$ for data (c) and for MC simulations on the processes $J/\psi \to \gamma\pi^0/\eta/\eta' \to 3\gamma$ (a), $J/\psi \to \gamma f(1270) \to \gamma(\gamma\gamma)_{\pi^0}(\gamma\gamma)_{\pi^0}$ (b), $J/\psi \to 3\gamma$ (d) and $J/\psi \to \gamma\eta_c \to 3\gamma$ (f). Plot (e) shows the distributions after excluding backgrounds from $J/\psi \to \gamma\pi^0/\eta/\eta'$. The vertical lines indicate the mass windows to reject π^0, η and η'.

Background study of $J/\psi \to \gamma e^+ e^-$

- if the electron and positron tracks fail to be reconstructed in the Main Drift Chamber, and the associated EMC clusters then being misidentified as photon candidates

- **To reject the background**
  - the number of hits in the MDC within an opening angle of five EMC crystals around the center of each photon shower is counted
  - the total number of hists from the three photons is required to be less than 40.



FIT

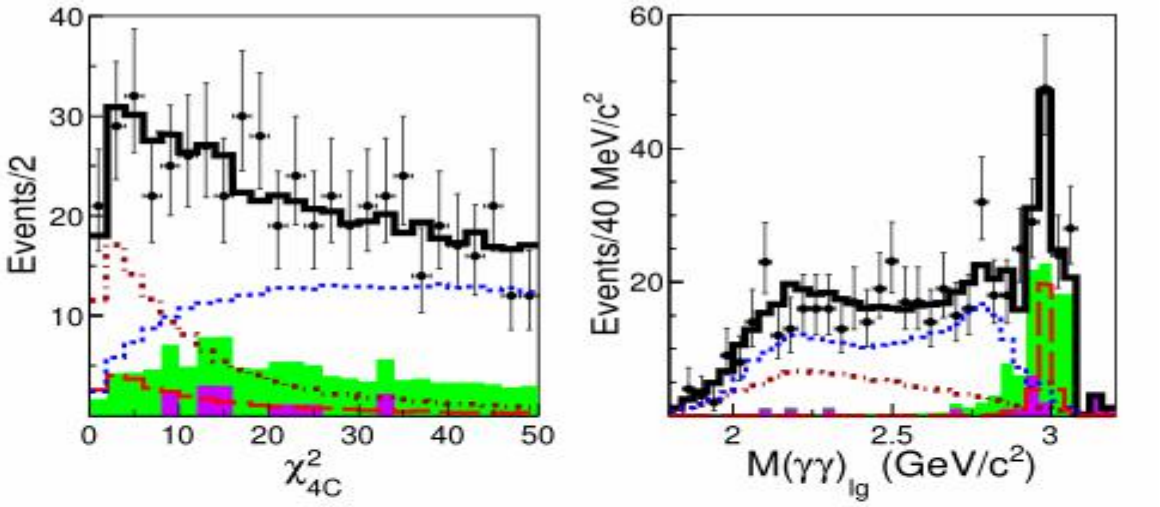


FIG. 3. (color online) Projection of the two-dimensional fit to χ^2_{4C} (left) and $M(\gamma\gamma)_{\rm lg}$ (right) for data (points with error bars) and the fit results (thick solid line). The (dark red) dotted-dashed, (red) dashed and (blue) dotted lines show contributions from $J/\psi \to 3\gamma$, $J/\psi \to \gamma\eta_c \to 3\gamma$, and $J/\psi \to \gamma\pi^0\pi^0$, respectively. The stacked histogram represents the backgrounds from $J/\psi \to \gamma\pi^0/\eta/\eta'$ (light shaded and green) and non-J/ψ decays (dark shaded and violet).

branching fraction is calculated using

$$\mathcal{B} = \frac{n_{\rm obs}}{N_{\psi(3686)} \times \mathcal{B}(\psi(3686) \to \pi^+\pi^- J/\psi) \times \varepsilon}$$

Summary and Highlights(1)

- with **106M psi(2S)** data sample, Eta_c decays to 2 photons could be reconstructed with high effeciency. And signal yied is about 33

Mode	$J/\psi \to 3\gamma$	$J/\psi \to \gamma\eta_c, \eta_c \to \gamma\gamma$
ε (%)	27.9 ± 0.1	20.7 ± 0.2
Yield	113.4 ± 18.1	33.2 ± 9.5
Significance	$8.3(7.3)\sigma$	$4.1(3.7)\sigma$
$\mathcal{B}(\times 10^{-6})$	$11.3 \pm 1.8 \pm 2.0$	$4.5 \pm 1.2 \pm 0.6$

- with psi(2S) data, it is more easier to suppress background.

Summary and Highlights (2)

- some interesting techniques were introduced in background study.
  - one could select good showers by requiring the number of MDC hits in an opening angle.
- this mode may be used as the normalizing channel in the possible upcoming analysis works

THANKS