Observation of h_c Radiative Decay $h_c \to \gamma\eta'$ and Evidence for $h_c \to \gamma\eta$

introduction of hc(1P) state

$c\bar{c}$ MESONS

$h_c(1P)$ $\quad I^G(J^{PC}) = ?^?(1^{+-})$

- P-wave(orbital angular momentum = 1) spin-singlet state.
- the observed decay channels only account for about 50% branching fraction
- due to its spin-parity:
  - hc could not be directly produced in e+e- collisions.
  - mainly decays into a photon(1--) and a pseudoscalar (0-+) through QED process.
- searching the new decay modes are useful for providing constraints to theoretical models.

Signal process

$$\psi' \to \pi^0 h_c$$
$$h_c \to \gamma\eta'$$
$$\eta' \to \pi^+\pi^-\eta$$
$$\eta \to \gamma\gamma$$
$$\eta' \to \gamma\pi^+\pi^-$$
$$h_c \to \gamma\eta$$
$$\eta \to \gamma\gamma$$
$$\eta \to \pi^+\pi^-\pi^0$$

hc is produced from Psi’ decay.
reconstruct eta’ with two decay modes

signal selection

4 plots shows results of these 4 signal processes, respectively.

$\psi' \to \pi^0 h_c$

$h_c \to \gamma\eta'$

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

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

$h_c \to \gamma\eta$

$\eta \to \gamma\gamma$

$\eta \to \pi^+\pi^-\pi^0$

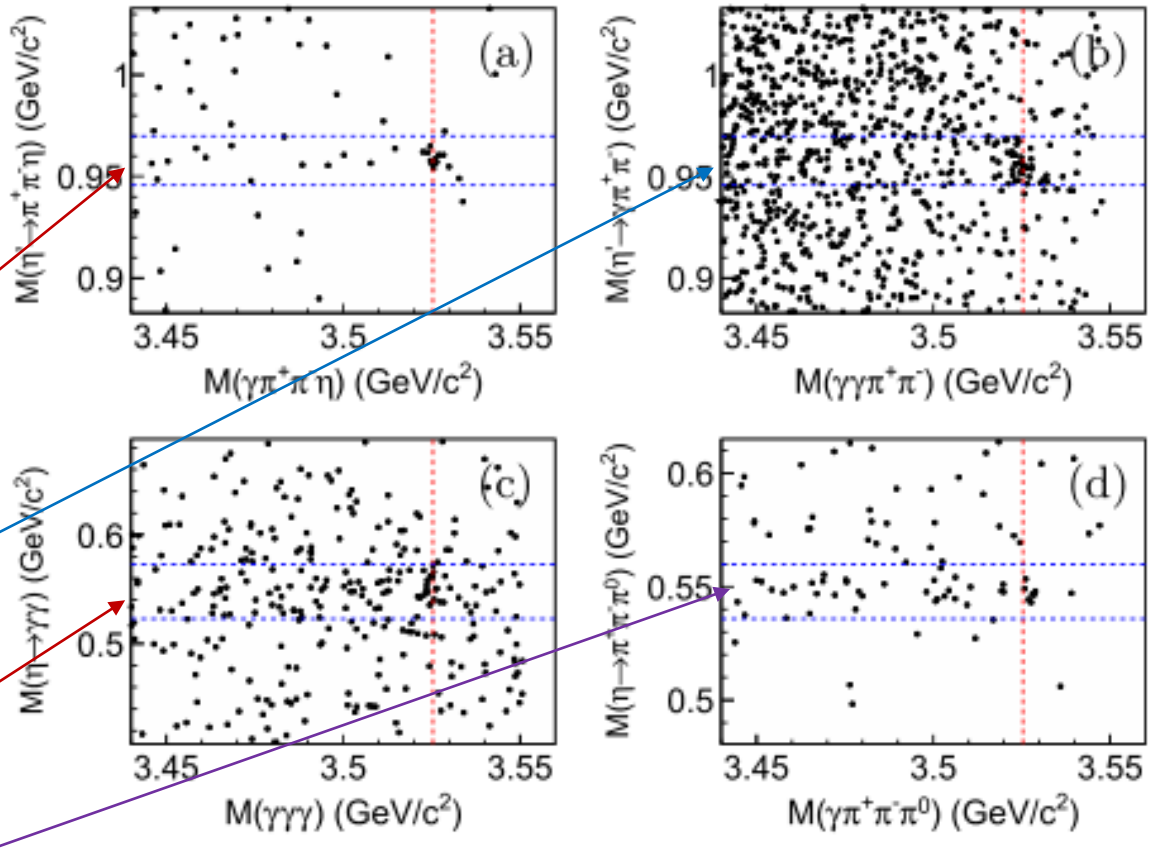


FIG. 1. Scatter plots of the selected events from the ψ' data set. (a) $M(\eta' \to \pi^+\pi^-\eta)$ versus $M(\gamma\pi^+\pi^-\eta)$ for $h_c \to \gamma\eta'(\eta' \to \pi^+\pi^-\eta)$. (b) $M(\eta' \to \gamma\pi^+\pi^-)$ versus $M(\gamma\gamma\pi^+\pi^-)$ for $h_c \to \gamma\eta'(\eta' \to \gamma\pi^+\pi^-)$. (c) $M(\eta \to \gamma\gamma)$ versus $M(\gamma\gamma\gamma)$ for $h_c \to \gamma\eta(\eta \to \gamma\gamma)$. (d) $M(\eta \to \pi^+\pi^-\pi^0)$ versus $M(\gamma\pi^+\pi^-\pi^0)$ for $h_c \to \gamma\eta(\eta \to \pi^+\pi^-\pi^0)$. The blue dashed lines mark the signal region of η' (η) and the red dashed lines mark the nominal h_c mass.

simultaneous fits

- The hc signal is identified by 4 decay chains.
- hence we could get hc signal peaks on 4 mass spectrums.
- All these 4 peaks are all hc signal peaks, we fit them simultaneously with the same PDF. model.

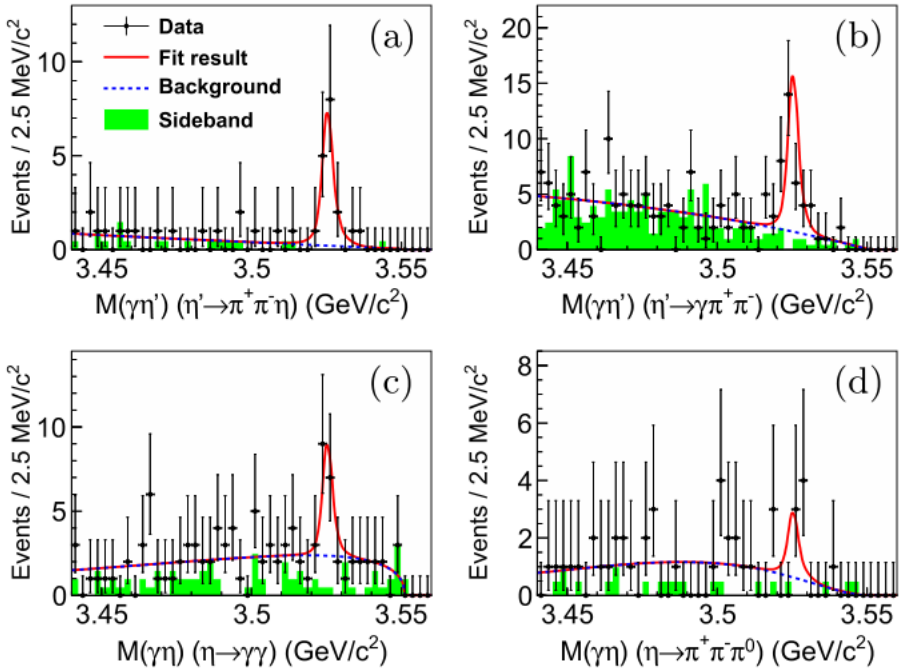


FIG. 2. Results of the simultaneous fits to the two invariant mass distributions of (top) $M(\gamma\eta')$ and (below) $M(\gamma\eta)$ for data. (a) $M(\gamma\eta')$ distribution for $h_c \to \gamma\eta'(\eta' \to \pi^+\pi^-\eta)$. (b) $M(\gamma\eta')$ distribution for $h_c \to \gamma\eta'(\eta' \to \gamma\pi^+\pi^-)$. (c) $M(\gamma\eta)$ distribution for $h_c \to \gamma\eta(\eta \to \gamma\gamma)$. (d) $M(\gamma\eta)$ distribution for $h_c \to \gamma\eta(\eta \to \pi^+\pi^-\pi^0)$. The red solid curves are the fit results, the blue dashed curves are the background distributions, and the green hatched histograms are events from the $\eta'(\eta)$ sidebands.

Summary of highlights in this paper

- BESIII firstly observed two new decay modes of hc.
- ratio of the branching fractions of these two observed decay modes could help to study the eta-eta’ mixing angle
- make sure you really understand the words “observation ” and “evidence” in the title of this paper.
- when searching for new resonance/decay modes with more than one decay chains, it is good to perform simultaneous fit, which could also improve the statistical significance.

Questions

Hao

- I want to ask you a easy question that what is hc?

- hc(1P) is a bond state of a charm quark and an anti-charm quark.
- the orbital angular momentum between ccbar is 1
- and its the spin-singlet state.
- By the way, the spin-triplet is ChicJ

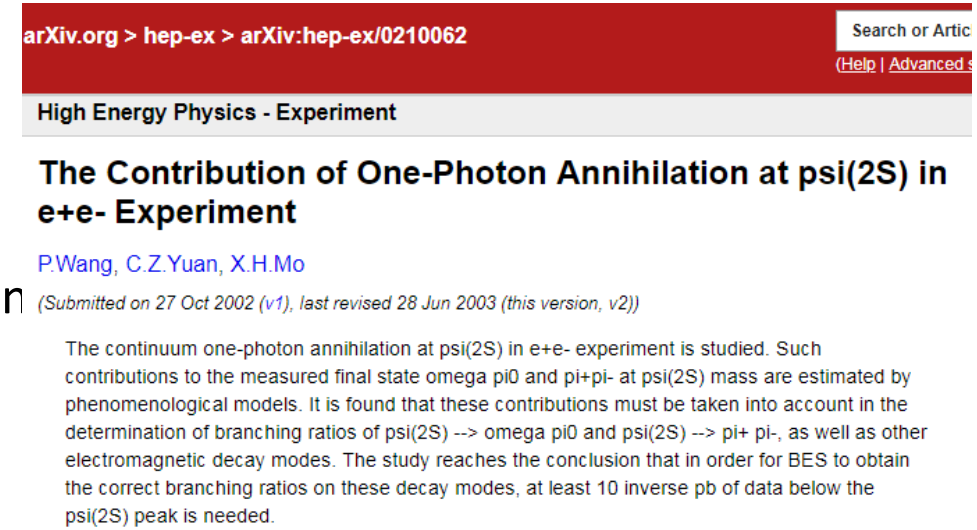
Maoqiang

- why they use 3650 data to estimate continuum background.

- The events taken at 3686 MeV mainly including two parts:
  - decays from psi'
  - continuum process
- To get the correct number of signal from psi' decay, we should eliminate the influence from continuum process.

The best way is to taken data just below the psi' production threshold.

- for more details, you could check this paper.



https://arxiv.org/abs/hep-ex/0210062

Ryuta

- **In the paper, they mentioned about the eta-etaprime mixing angle, but is there any theoretical model or number for that ?**
- **Here I show you the two most famous papers of this issue.**
  - one is from H.Fritzsch, who proposed the “color” freedom of quarks with M.Gellman, and he is also one of the fathers of QCD theory. An active top level physicist.
  - another is from Chao Kuang-Ta, a very famous Chinese theoretical physicist in Peking University. He also contribute a lot for BESI/II/III physics.

MIXING OF PSEUDOSCALAR MESONS AND M1 RADIATIVE DECAYS

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MIXING OF η, η' WITH $c\bar{c}, b\bar{b}$ STATES AND THEIR RADIATIVE DECAYS

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Physics at *BES-III*

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Suyu

- From Table II, we can see the systematic uncertainties. From my point of view, signal shape plays a more important role than fit range.
- And uncertainty from Fit Range is larger than that from Signal Shape for eta'.
- But for eta, why is the uncertainty from Fit Range larger than that from Signal Shape?
- Is it physical?

- Which source contributes more in the systematic uncertainty depends on the distribution, PDF, etc, there isn't any **certain rule** that one source should more important than another.
- In this paper, the eta signal peaks appears with lower statistical significance, and suffers low statistics. When changing fit range, the newly included events may have large influence on the goodness of fit.