Study of γ conversion at BESII

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Abstract

We identify photons which convert inside our detecter near the beam pipe, and all oppositely charged track pairs of given hemisphere in which at least one track is identified as an electron is considered. Using this method, the energy resolution of converted photons can reach around $1.5\%\sqrt{E}$ at $E_\gamma = 0.75GeV$ at BESII, it can be compared with that of Crystal ball experiments. So, using new J/ψ data collected during the last run at BESII, we study the converted photon spectrum in order to probe J/ψ radiative decays, clear signals near $E_\gamma = 1.21$, 1.40, 1.50 and 1.548 GeV are found corresponding to $\eta(1440)$, η', η and $e^+e^- \to \gamma\gamma$ respectively. A narrow signal appears near $E_\gamma = 0.745$GeV, which suggest a narrow resonance may exist near 2.230 GeV.

1 Introduction

It is well known that J/ψ radiative decays is one of the best place to learn about glueball states. In J/ψ radiative decays, two gluons are the minimum number required by quantum numbers and those form the basis for the lightest scalar and tensor glueballs [1].

Among those glueball candidates, $\xi(2230)$ is a disputed one from both experiment and theory [2]. In order to confirm the existence of $\xi(2230)$, we must probe it in different decay modes, such as $\xi(2230) \to \pi^0\pi^0$, $\eta\eta$, $\eta\eta'$ and $\eta'\eta'$ [3] which include multi-photon final states. BES experiment is the only running J/ψ experiment using e^+e^- collider at the Beijing Electron-Positron Collider(BEPC), but our calorimeter BSC has a poor energy resolution $\sim 23\%/\sqrt{E}$, It is very difficult for us to probe the properties -of $\xi(2230)$ completely, even if we have larger J/ψ sample at BESII.

In this analysis, we identify photons which convert to a e^+e^- pair inside our detecter near the beam pipe, the momentum of electron-positron can be detected in MDC which momentum resolution is $1.8\%\sqrt{1+p^2}$, the energy of e^+e^- system is almost equal to the energy of converted photon, so the energy resolution is improved greatly, it can be compared with that of Crystal ball experiments. Then we can show the energy of e^+e^- system from γ conversion to study the radiative γ energy spectrum in J/ψ decays. Assuming $\mathrm{Br}(J/\psi \to \gamma\xi(2230)) = 3\times10^{-3}$ [2] is correct, there should be at least ~ 900 $e^+e^-\xi(2230)$ events, which $\xi(2230)$ to anything, using 10M BESII J/ψ data any narrow peak in the energy spectrum of

e^+e^- system will give us a lot of excited information. This method is the only way to know the absolute production rate of ξ (if it does exist) in J/ψ decays! All other methods only measure the production of ξ rate and the rate of ξ to some specific channels.

The content of this note is as following: In section 2, the properties of γ conversion at BESII are studied in detail using Monte Carlo data. In section 3, optimum cuts are selected in order to reduce the background from no-radiative γ conversion. In section 4, the results of real data at BESII are shown, clear signals near $E_\gamma = 1.21$, 1.40, 1.50 and 1.548 GeV are found corresponding to $\eta(1440)$, η', η and $e^+e^- \to \gamma\gamma$ respectively. A narrow signal appears near $E_\gamma = 0.745$GeV, which suggest a narrow resonance may exist near 2.230 GeV.

2 Monte Carlo Study of γ Conversions

In order to understand the properties of γ conversion at BESII, A full Monte Carlo simulation is performed at different γ energy points, we produced 10K single photon events at $E_\gamma = 0.35$, 0.5, 0.75, 1.0 1.2 and 1.5 GeV respectively. The probability of γ conversion should depend on the energy of converted photons [4], but, at BESII, 2.8% for different energy photons to convert to e^+e^- pairs are fixed for Monte Carlo data.

Fig. 1 shows the relation between energy of e^+e^- pair system and energy of converted photons, one can conclude that $E_{e^+e^-} = E_\gamma$, for example, the energy difference between them is less than 0.1% at $E_\gamma = 0.75$ GeV. The energy resolution of e^+e^- system is shown in Fig. 2, it can be fitted as $\delta E = 3.7\%\sqrt{E} - 0.018$ (E in GeV), for example, $\delta E = 1.5\%\sqrt{E} = 12$ MeV at $E_{e^+e^-} = 0.75 GeV$ this results is even better than that of Crystal ball experiments. So we can try to probe γ energy spectrum using converted photons.

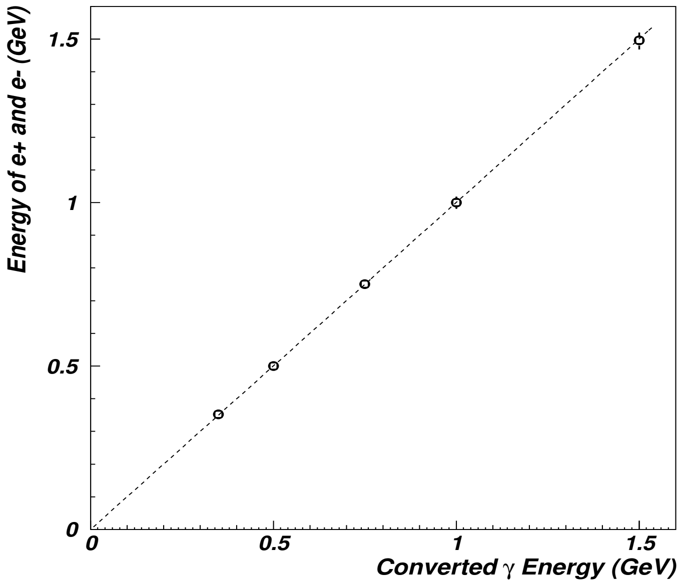

Figure 1: Energy of e^+e^- system via converted γ energy(MC data)

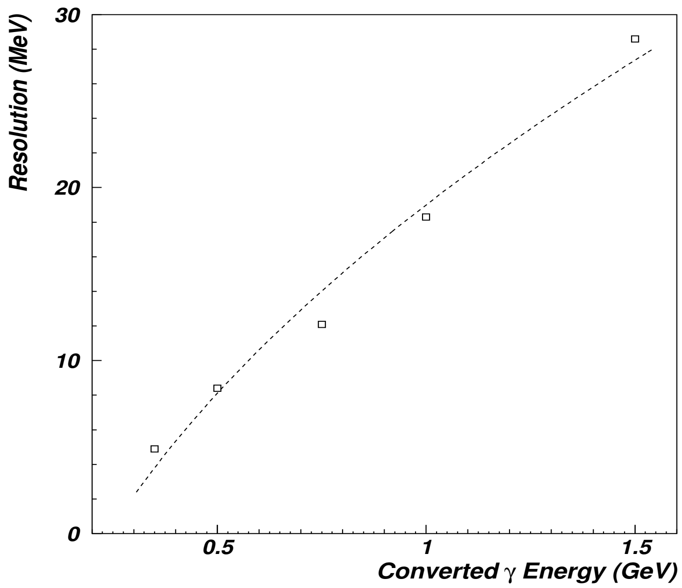

Figure 2: The Energy resolution of $E_{e^+e^-}$ via converted γ energy

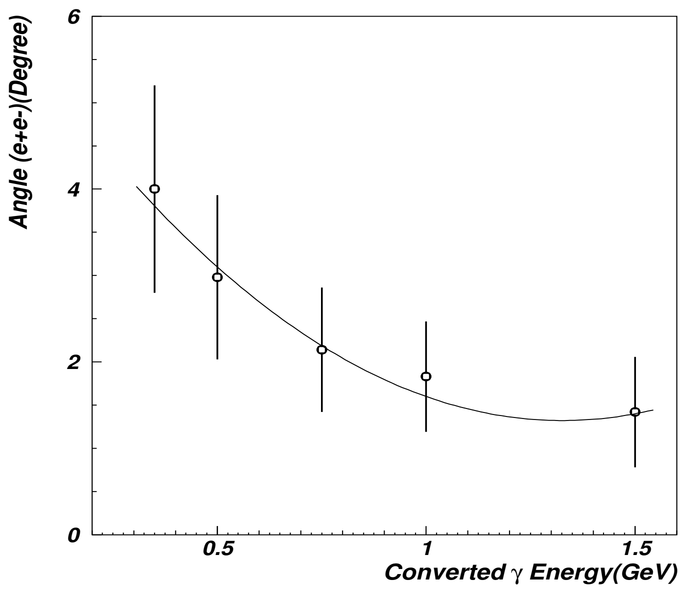

Figure 3: Plots of the angle between e^+ and e^- via converted γ energy(MC data)

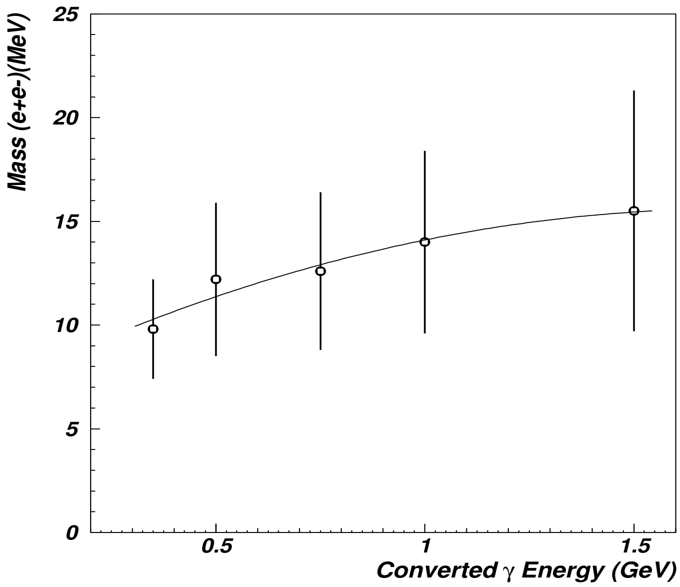

Figure 4: Plots of inv. mass of e^+e^- via converted γ energy(MC data)

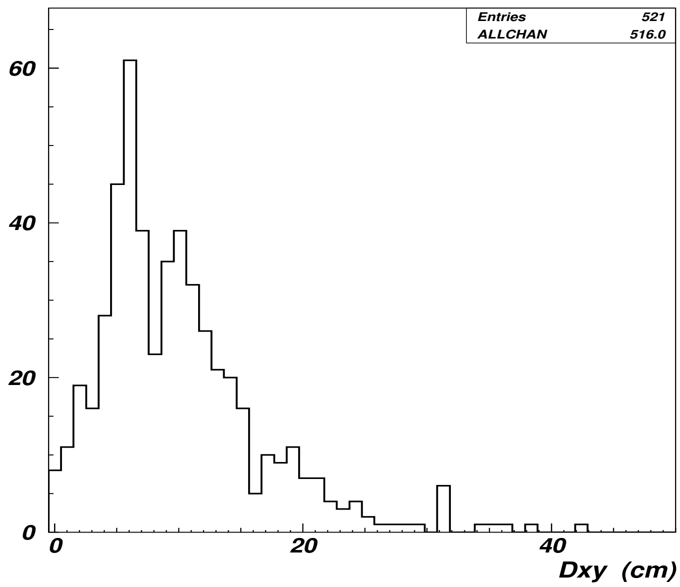

Figure 5: The distribution of conversion points (MC data at $E_\gamma = 0.75$ GeV)

In order to understand the event shape of converted γ candidates, many Monte Carlo simulation are performed. Fig. 3 gives the angle distribution between e^+ and e^- at different energy of converted photons, and Fig. 4 shows the invariant mass of e^+e^- pair at different energy points. At $E_\gamma = 0.75GeV$ point, the e^+e^- pair from γ conversion should have an invariant mass smaller than 30 MeV from Fig. 4, and the angle between e^+ and e^- is less than 5^o from Fig. 3, we will use the angle cut to select those candidates since the spatial resolution is perfect in our Main Drift Chamber(MDC). Monte Carlo result in Fig. 5 give us the distribution of distance between conversion points and interaction point in xy plane, one can find that most of the conversion points should be near beam pipe at BESII, namely near 5cm.

3 Background Analysis

The main backgrounds could be from the following lists:

- Background from $e^+e^- \to \gamma\gamma(\gamma)$, in which any of gammas converts into e^+e^-. Fig. 6 shows $E_{e^+e^-}$ distribution from $e^+e^- \to \gamma\gamma(\gamma)$ Monte Carlo data. Most of them can be almost removed, if $N_{charge} > 2$ cut is applied, where N_{charge} is the total number of charged tracks in MDC.
- Background from $e^+e^- \to e^+e^-(\gamma)$, it can be rejected by using small angle cut between e^+ and e^-.
- Background from π^0 dalitz decay and $\gamma\gamma$ decay, we can use $|M_{e^+e^-\gamma} - M_{\pi^0}| > 0.09$GeV cut to remove this kind of bacground as showed in Fig. 7.
- Background from multi-photon final state decays, it is hard for us to remove those type noise, but most of those events accumulate near low energy region on $E_{e^+e^-}$ spectrum as showed in Fig. 8.

4 Event Selection

From study of Monte Carlo simulation and background analysis, we understand well the event shape of gamma conversion at BESII. Using new J/ψ data collected during the last run of BESII, we identify the converted photons in order to study the radiative gamma energy spectrum in J/ψ decays.

The following event shapes are required:

- N_{charge} is great than 2.

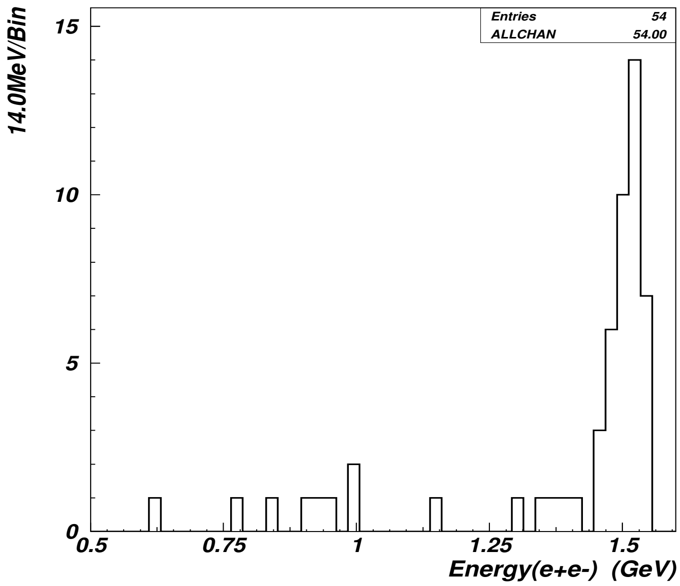

Figure 6: The distribution of $E_{e^+e^-}$ from $e^+e^- \to \gamma\gamma$(MC data)

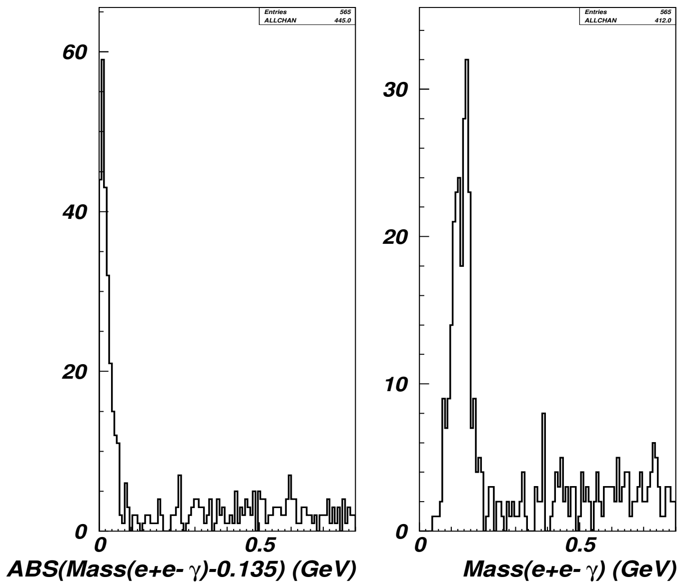

Figure 7: The distributions of $M_{e^+e^-\gamma}$(right); and $|M_{e^+e^-\gamma} - M_{\pi^0}|$ (left) (MC data)

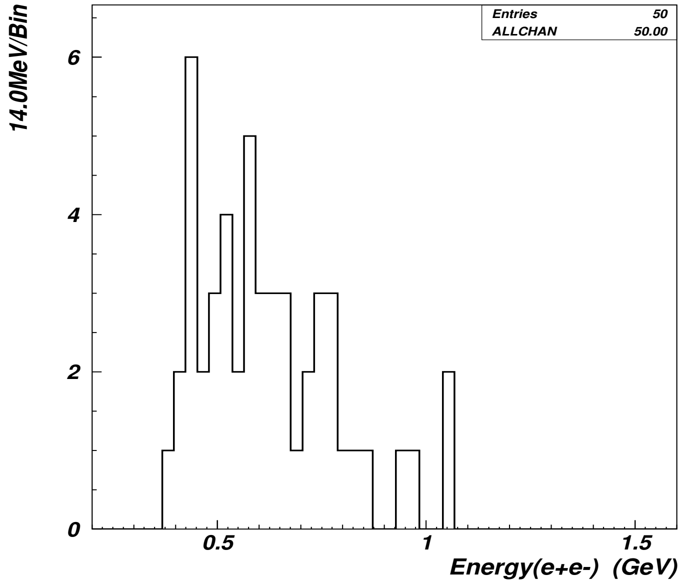

Figure 8: The distribution of $E_{e^+e^-}$ from $J/\psi \rightarrow anything$(MC data)

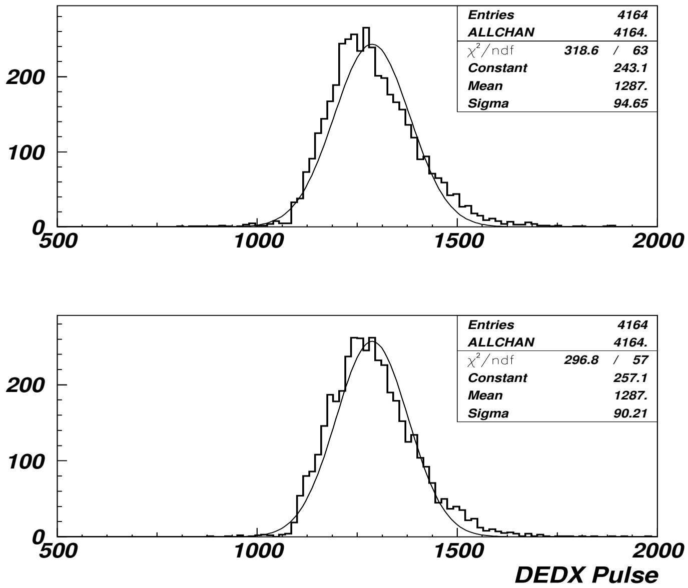

Figure 9: The distributions of DEDX puleses(upper for electron and lower for positron (real data)

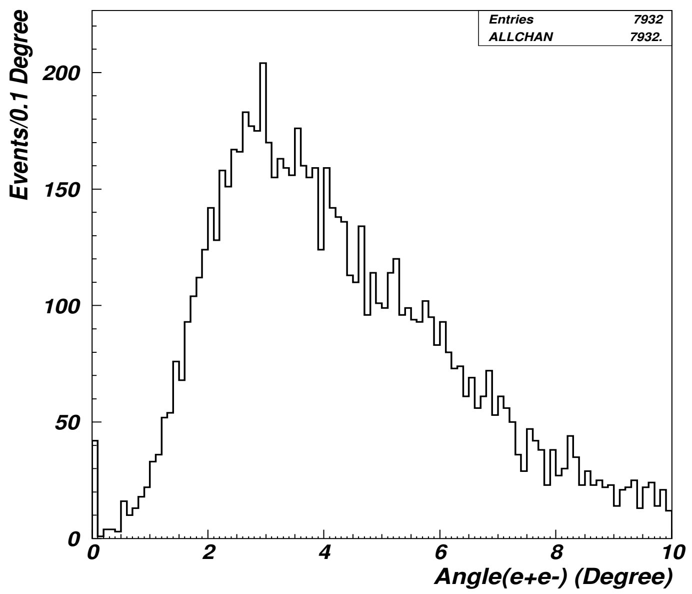

Figure 10: The distributions of angle between e^+ and e^- for real data

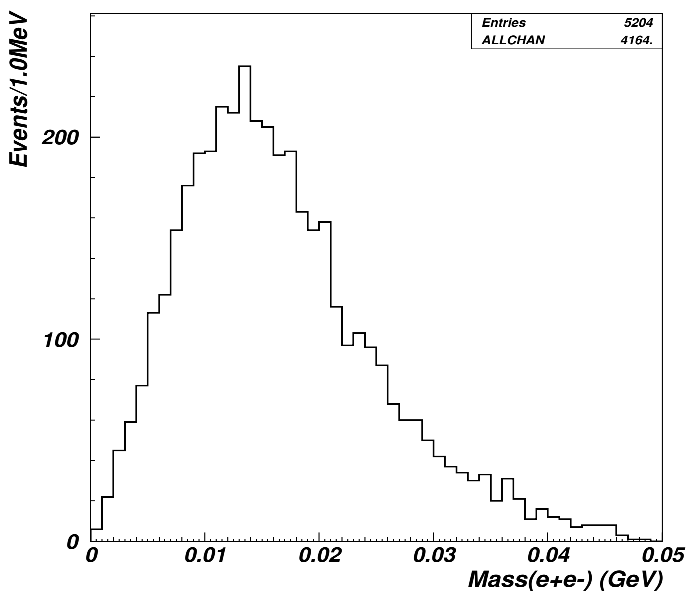

Figure 11: The distributions of inv. mass of e^+e^- for real data

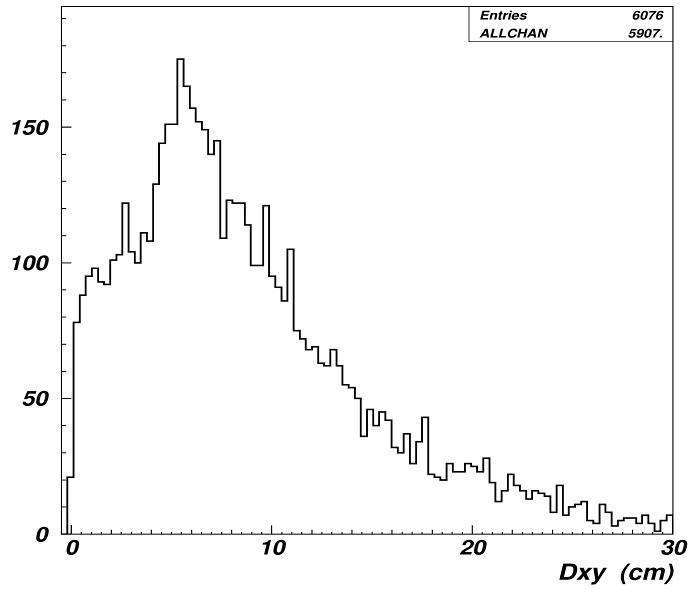

Figure 12: The distribution of conversion points(real data)

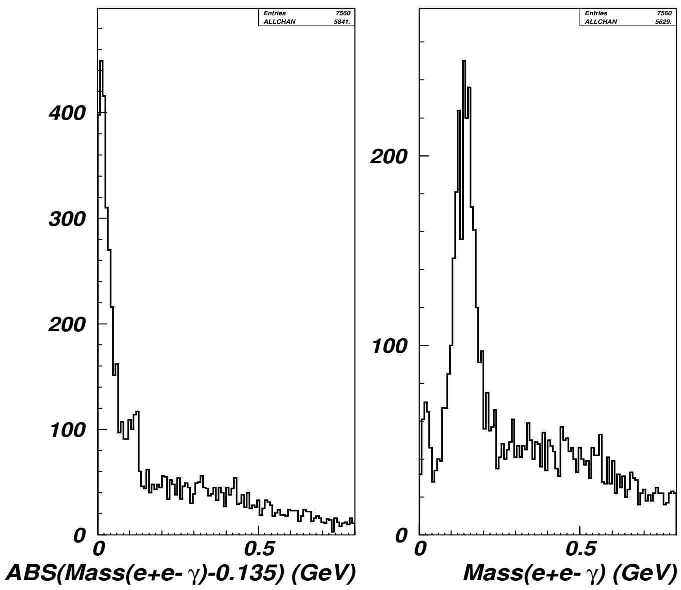

Figure 13: The distributions of $M_{e^+e^-\gamma}$(right); and $|M_{e^+e^-\gamma} - M_{\pi^0}|$ (left) (real data)

- In order to identify photons which covert inside our detecter, all oppositely charged track pairs in which at least one track is identified as an electron are considered, here, we use DEDX information to identify electron, asking $(PH_{DEDX} - 1290) < 270$, where $(PH_{DEDX}$ is the corrected DEDX pulse from MDC. Fig. 9 shows the DEDX pulse distribution from real J/ψ data at BESII.

- At least one e^+e^- pair is needed.

- The angle between e^+e^- less than 3.8^o, Fig. 10 shows the angle distribution.

- The inv. mass of e^+e^- less that 50 MeV as shown in Fig 11.

- The momentum of any electron or positron should be less than $\frac{E_{cm}}{2}$;

- We try to find the conversion points, and asked that $0.05 < D_{xy} < 0.4$ m. where D_{xy} is the distance between the second vertex and the interaction point at xy plane. Fig. 12 shows D_{xy} distribution, we can see that most of coversion points are near beam pipe position.

- $\chi^2_{xy} < 10$, where χ^2_{xy} (1 dof) of xy alignment of parent momentum with line from interaction point

- To remove background from π^0 dalitz decay and $\gamma\gamma$ decay, we ask $|M_{e^+e^-\gamma} - M_{\pi^0}| >$ 0.09GeV as shown in Fig. 13.

- Because most of photon convert near beam pipe, the energy loss is a different case from that of charged track emitted from the interection point, here, we cancel the energy correction to beam pipe case.

In order to check our electron ID, we show the $\frac{E_{e^\pm}}{P_{e^\pm}}$ distribution in Fig. 14, where $E_{e^\pm}$ is the deposite energy of electron in BSC. In addition, we select converted photons from $e^+e^- \rightarrow \gamma\gamma$ events to calibrate the energy of e^+e^- system, from Fig. 15, we can see the fitted center value is 1.560GeV, it is about 11.5 MeV shift from the expected value. So the momentum measurement of e^+ and e^- in MDC should be corrected, and we can use the following correction factor δE at $E_\gamma = \frac{E_{cm}}{2}$ point:

$$\delta E = \frac{0.0115}{1.560}$$

Here, we assume the same correction factor is used to correct the energy in all energy region.

Fig. 16 shows us the $E_{e^+e^-}$ spectrum, the vertical lines are position of converted photons corresponding to the X particle in J/$\psi \rightarrow \gamma X$ radiative decays. Clear signals near $E_\gamma = 1.21$, 1.40 and 1.50GeV are found corresponding to $\eta(1440)$, η' and η repectively. A narrow signal appears near $E_\gamma = 0.745$GeV, which suggest a narrow resonance may exist near 2.230 GeV with 2.5σ statistic significant.

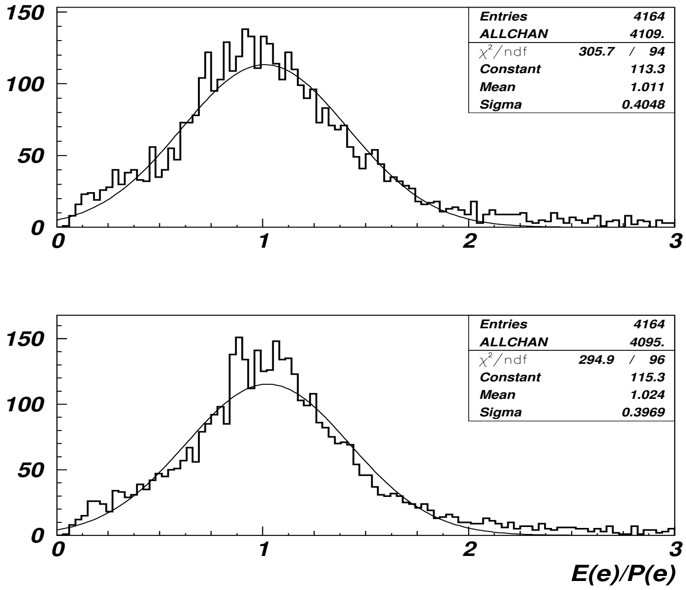

Figure 14: The distributions of $\frac{E_{e^\pm}}{P_{e^\pm}}$ (upper for electron and lower for positron)

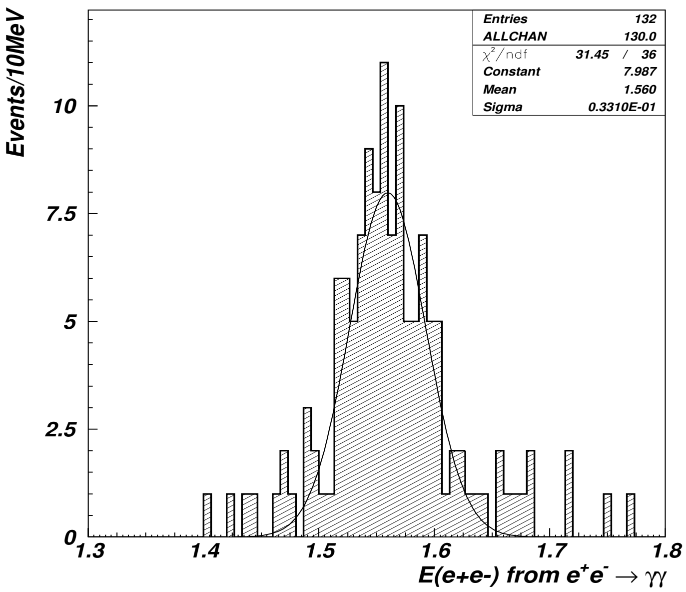

Figure 15: The distribution of $E_{e^+e^-}$ from $e^+e^- \to \gamma\gamma$(real data)

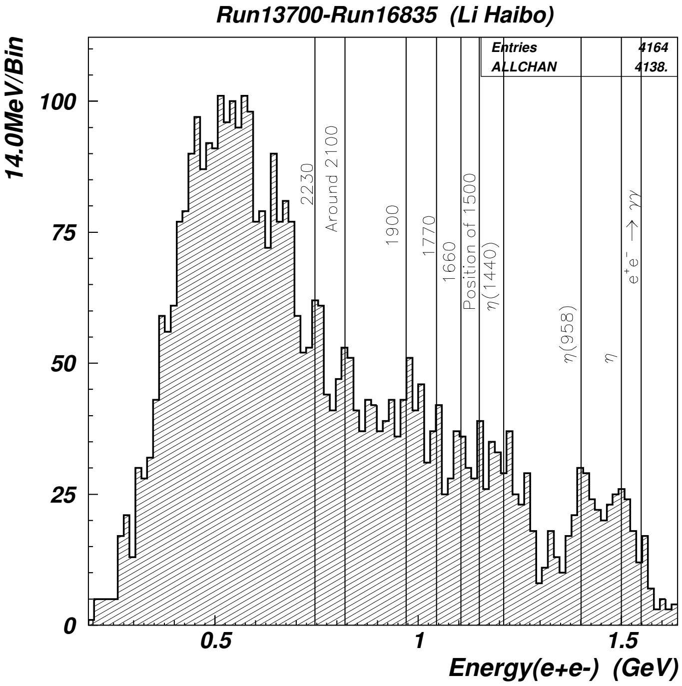

Figure 16: The distribution of $E_{e^+e^-}$ from J/ψ data, the vertical lines are position of converted photons corresponding to the X particle in J/$\psi \to \gamma X$ radiative decays

5 Conclusion and Future

We have identified photons with its conversion reaction in BESII, this method can avoid the poor BSC measurement of photon energy. The energy resolution of $E_{e^+e^-}$ is improved greatly, from Fig. 2 it can be fitted as $\delta E = 3.7\%\sqrt{E} - 0.018$ (E in GeV).

Using new J/ψ data collected at BESII, we have studied converted photon energy spectrum, clear signals near E_γ = 1.21GeV, 1.40 GeV and 1.50 GeV and are found corresponding to $\eta(1440)$, η' and η respectively. A narrow signal appears near $E_\gamma = 0.745$GeV, which suggest a narrow resonance may exist near 2.230 GeV with 2.5σ, assuming the probability of convertion is 3% at BESII, the selection efficiency is 10%, and the total number of online J/ψ number is 20M presently, we can roughly estimate the $Br(J/\psi \to \gamma\xi(2230)) = 0.5 \sim 0.9 \times 10^{-3}$(if it really exist). At the same time, we can also get the $Br(J/\psi \to \gamma\eta' = 4.0 \times 10^{-3}$(about 165 events and total efficiency is about 0.25%), while it is $(4.3 \pm 0.3) \times 10^{-3}$ from PDG98. We expect a larger J/ψ sample is collected and see more clear signal.

From BESI [2] and MARKIII [5] results, we can get $B(J/\psi \to \gamma\xi) \times B(\xi \to K\bar{K}) = 8.7 \times 10^{-5}$. Assuming $B(J/\psi \to \gamma\xi) = 0.7 \times 10^{-3}$ is correct, we can obtain:

$$B(\xi \to K\bar{K}) = 0.124$$

With LEAR experimental results at CERN [6], $B(\xi \to p\bar{p}) \times B(\xi \to K_sK_s) < 7.5 \times 10^{-5}$, we could conclude that:

$$B(\xi \to p\bar{p}) < 2.0 \times 10^{-3}$$

or:

$$B(J/\psi \to \gamma\xi)\dot{B}(\xi \to p\bar{p}) < 1.4 \times 10^{-6}$$

Finally, one suggest that we can add a thin slice material near interaction point inner beam pipe to increase the probability of convertion up to $20 \sim 30\%$, it will be able to see more clear signals.

Anyway, a new Barrel electromagnetic calorimeter (BEMC) should be constructed in the future, it can solve all problem, and produce rich physics results.

6 Acknowledgements

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