Study of the $\psi(2S) \rightarrow e^+e^-\chi_{cJ=0,1,2}$ and $e^+e^- \rightarrow e^+e^-X(3872)$

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Motivation

1. $e^+e^- \to e^+ e^- X$ is an electromagnetic (EM) Dalitz decay in which the virtual photon internally converte into a lepton pair. The q^2 dependent EM transition form factor can provide additional information on the interactions between charmonium states and the electromagnetic fields, and can help to probe their structures.

2. BESIII have reported the decay $\psi(2S) \to e^+e^- \chi_{cJ}$, $\chi_{cJ} \to \gamma J/\psi$, but only 48 yields χ_{c0} . It would be very interesting to measure the branching by using e^+e^- recoiling method.

3. $e^+e^- \to \gamma X(3872)$ was found with statistical significance 6.3σ at BESIII. $X(3872)$ is very narrow state with $J^{PC}= 1^{++}$. So it would be very possible to search for this EM Dalitz decay $e^+e^- \to e^+e^- X(3872)$.

Method

We circle all the tracks of $e^+ e^-$ candidates. If more the one combinations, we keep all of them. Then we look at the recoiling mass of $e^+ e^-$ pair. By fitting the recoiling mass distribution, then get the yields of signal.

$$\text{Rec\_mass}(e^+e^-) = \sqrt{(E_{beam} - E_{e+} - E_{e-})^2 - (p_{e+} + p_{e-})^2}$$

DIY MC model, Assuming pointlike particles, the electron pair is formed by internal conversion of an intermediate virtual photon with invariant mass $q=M(e^+e^-)$. Same as BESIII previous work PRL 118, 221802 (2017).

$$\frac{d\Gamma(\psi' \to e^+e^-\chi_{cJ})}{dq^2} \propto \frac{1}{q^2}(1+\frac{2m_e^2}{q^2})(1-\frac{4m_e^2}{q^2})^{1/2}[(1+\frac{q^2}{m_{\psi'}^2-m_{\chi_{cJ}}^2})^2 - \frac{4m_{\psi'}^2 q^2}{(m_{\psi'}^2-m_{\chi_{cJ}}^2)^2}]^{1/2}$$

Data Sample

1. Data

4.481× 10^8 $\psi(2S)$ events taken at $\sqrt{s}$ =3.686 GeV in 2009 (107.0 M) and 2012 (341.0 M).

2. Inclusive MC

3686 : 506 M official inclusive MC samples.

3. Signal MC

$\psi(2S) \rightarrow e^+e^-\chi_{cJ=0,1,2}$ 1690K , 150000 , 150000.

4. BOSS Version 6.6.4.p03

Event Selection

1. Good charged Tracks Selection

$|r_{xy}| < 1$ cm

$|r_z| < 10$ cm

$|\cos\theta| < 0.93$

2. Electron PID

dE/dx + TOF + EMC

prob(e) >0

prob(e) > prob(π)

prob(e) >prob(K)

prob(e) >0.8*[prob(e)+prob(π)+prob(K)]

3. Gamma

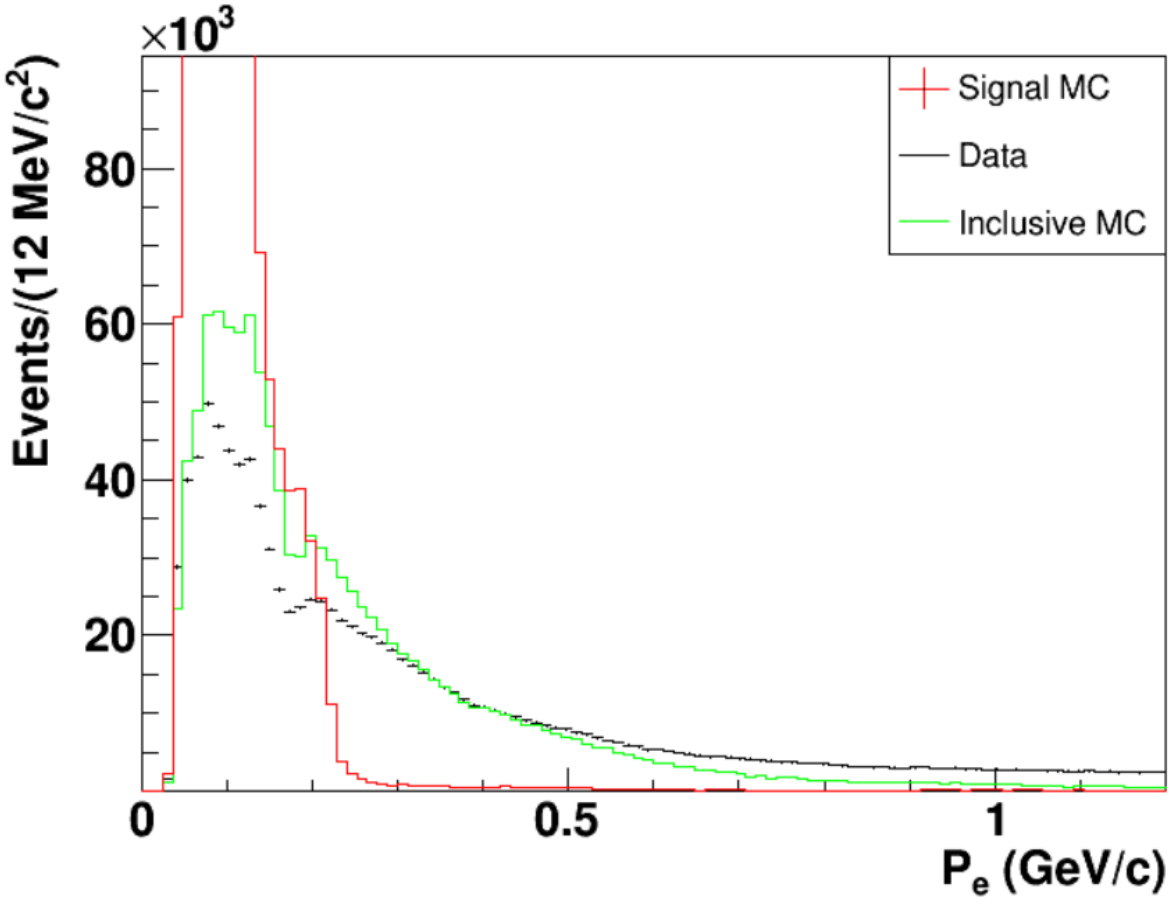
Barrel: E_{min} >25 MeV

Endcap: E_{min} >50 MeV

TDC: [0,14] (×50ns)

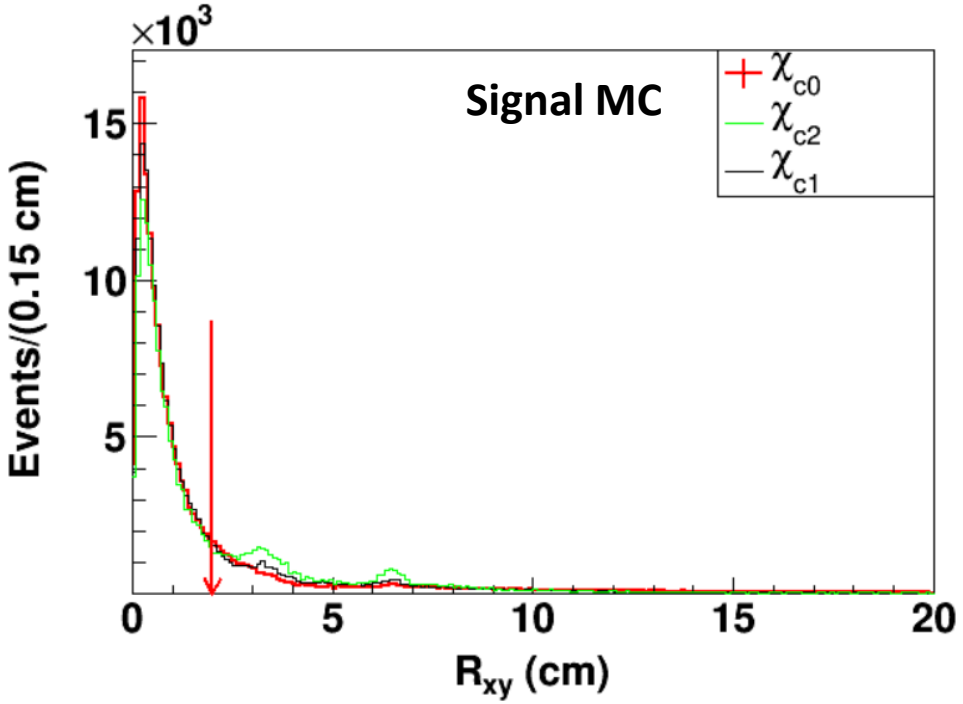
Momentum of electron

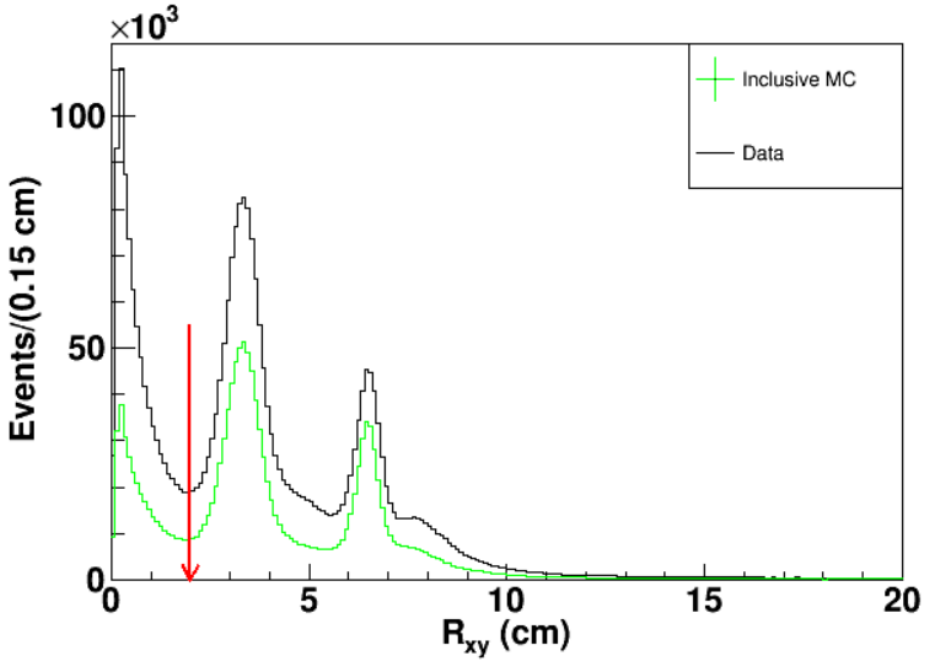
Simply require p_e< 0.3 GeV/c



Gamma Conversion

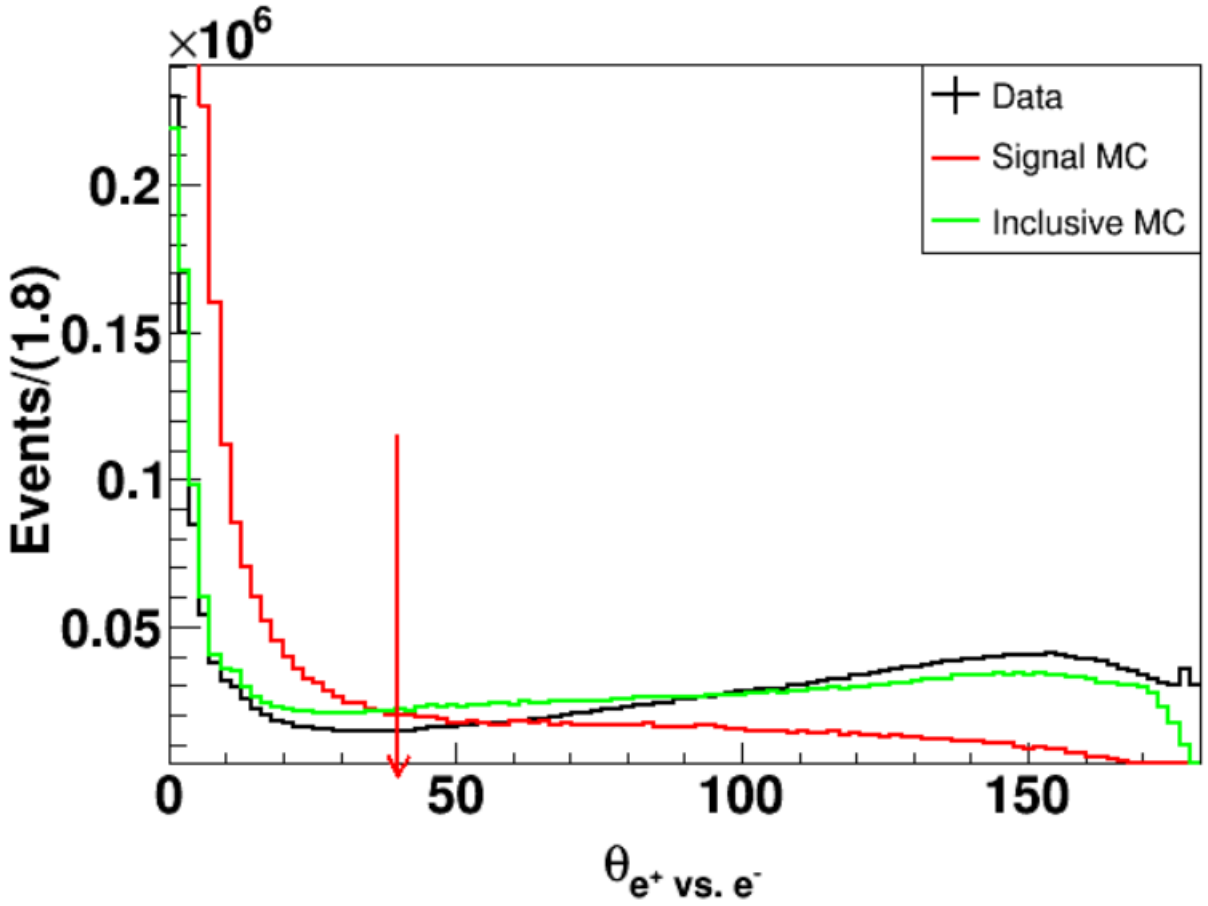
1. The photon may convert into an e^+e^- pair in the beam pipe or inner of MDC
2. R_{xy} is the distance from the reconstructed vertex point of electron-positron pair to point (0; 0; 0) in x - y plane.
3. We require $R_{xy} < 2$ cm to suppress γ conversion events.





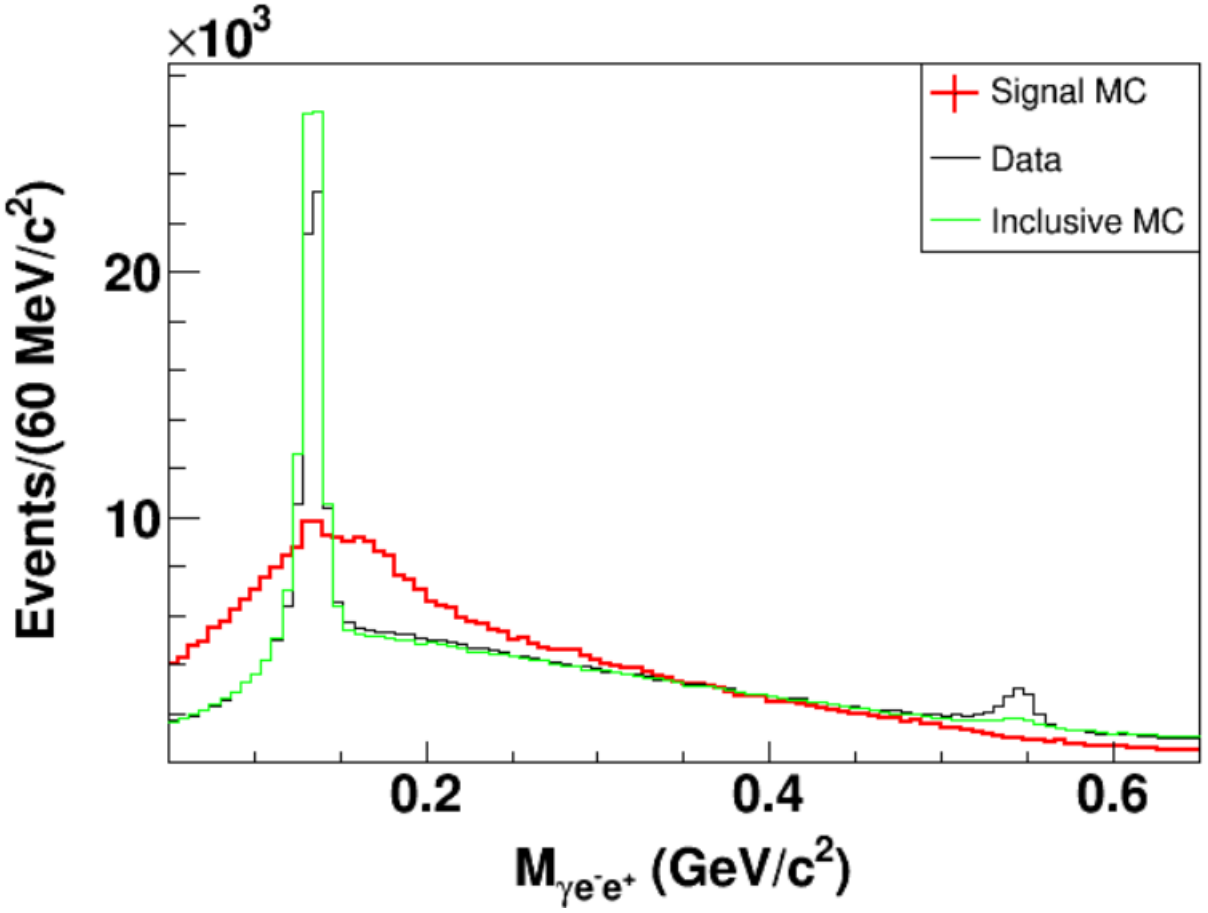
Angle between e^+ with e^-

Require $\theta_{e+ \text{ vs. } e-} < 40°$

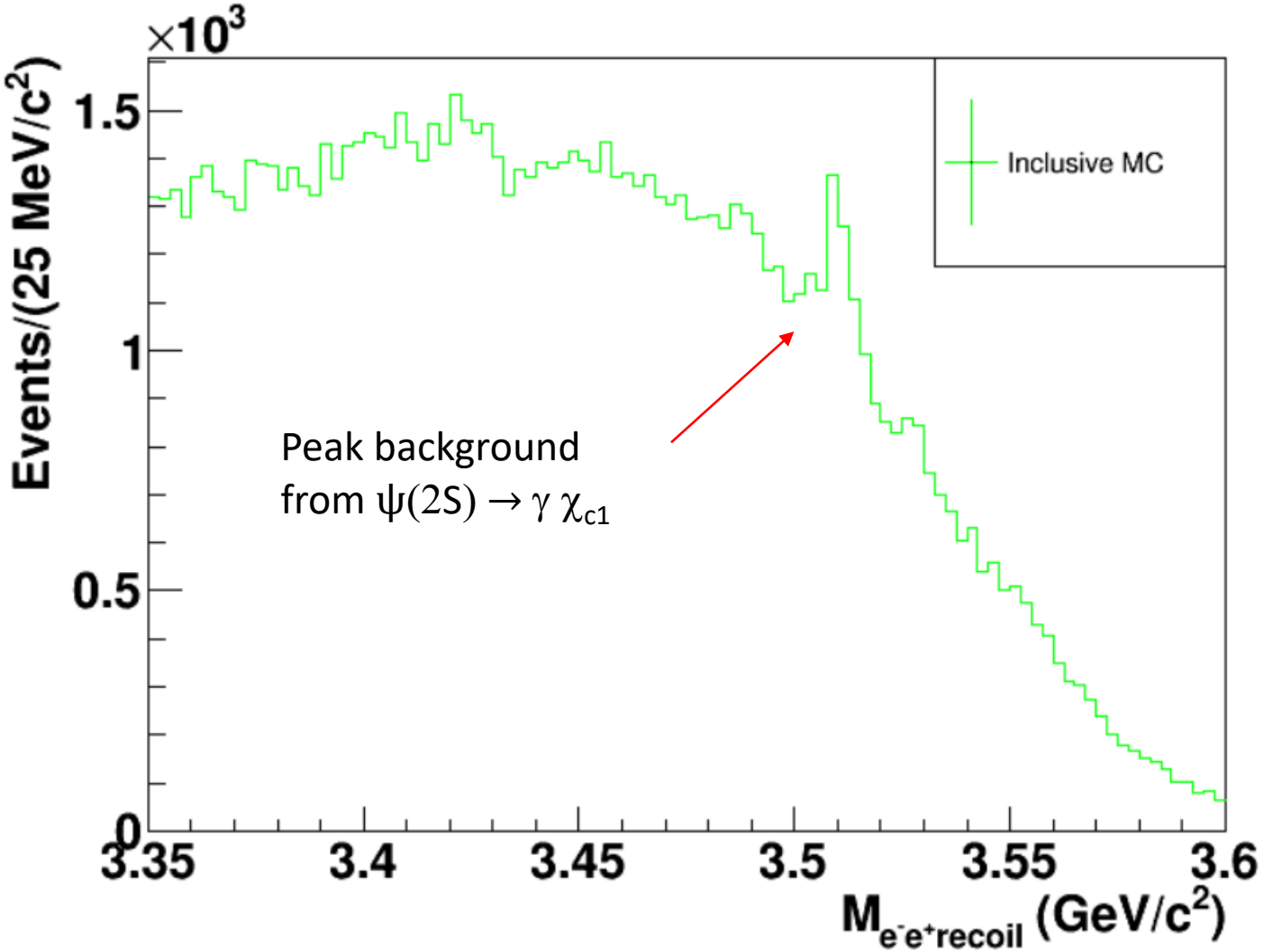


Veto $\pi^0/\eta \to \gamma e^+e^-$ Events

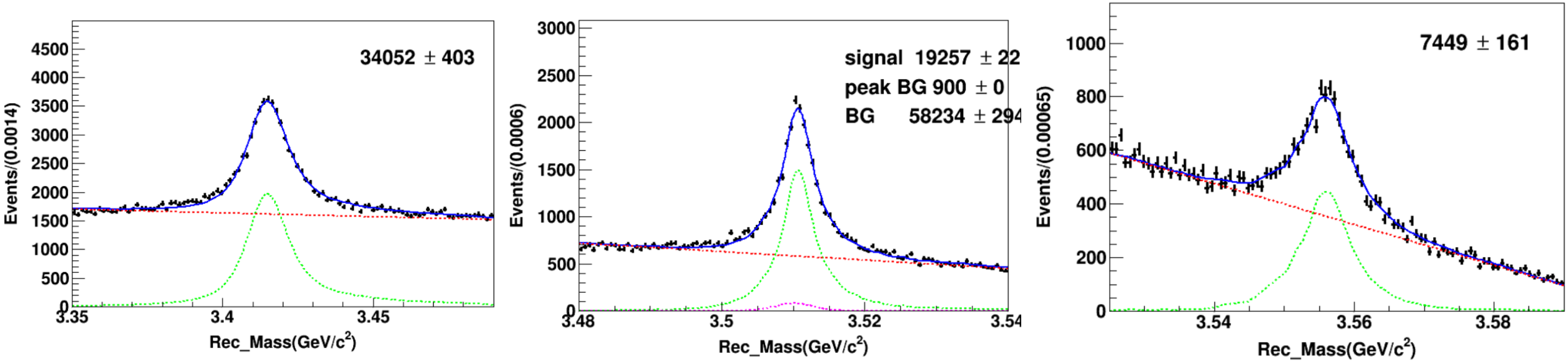
We check the invariant mass of γe^+e^- , once the $M_{\gamma e+e-}$ in the region of $\pi^0(0.115,0.150)$ GeV/c^2 or $\eta(0.505,0.570)$ GeV/c^2 , it's taken as $\pi^0/\eta \to \gamma e^+e^-$ process.



Rec_mass of $e^+ e^-$ Inclusive MC



Rec_mass of e^+e^- data



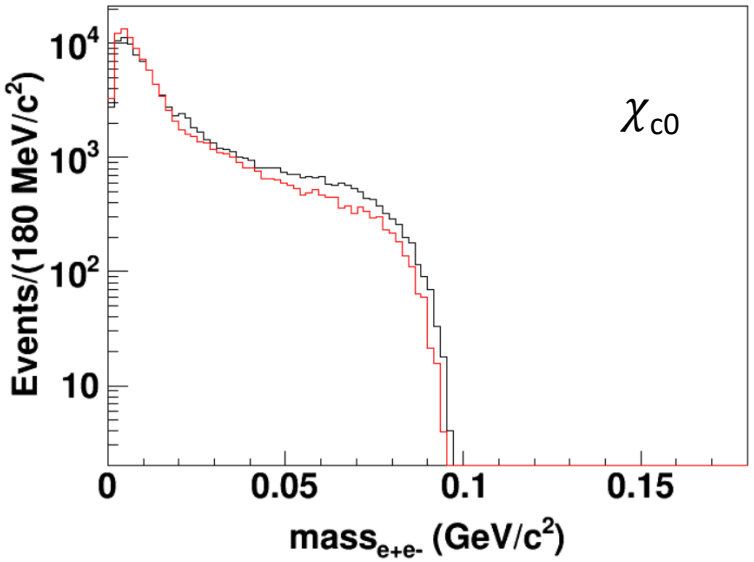
Signal Shape: MC shape⊗ Gauss (m , σ)
Background: 2th polynomial.

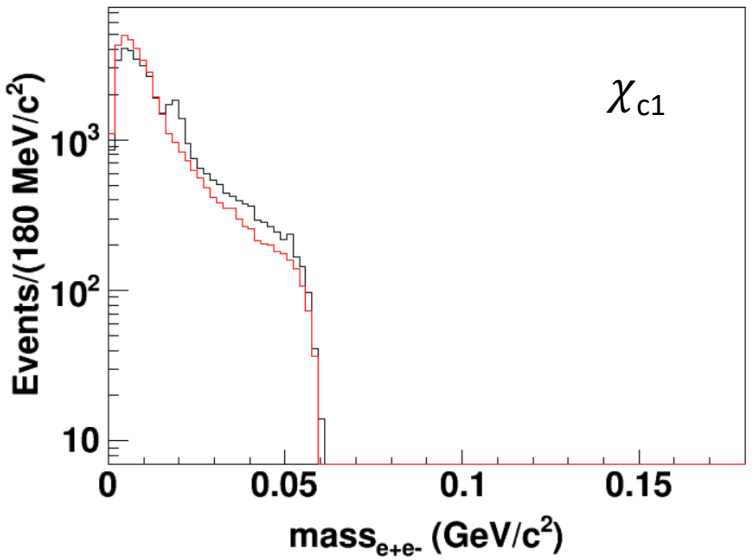
Peak background in $\psi(2S) \rightarrow e^+e^-\chi_{c1}$: a Gauss function and the parameters is fixed according to the Inclusive MC fit, the number of peak background is scaled by $\psi(2S)$ number in data over the number in Inclusive MC.

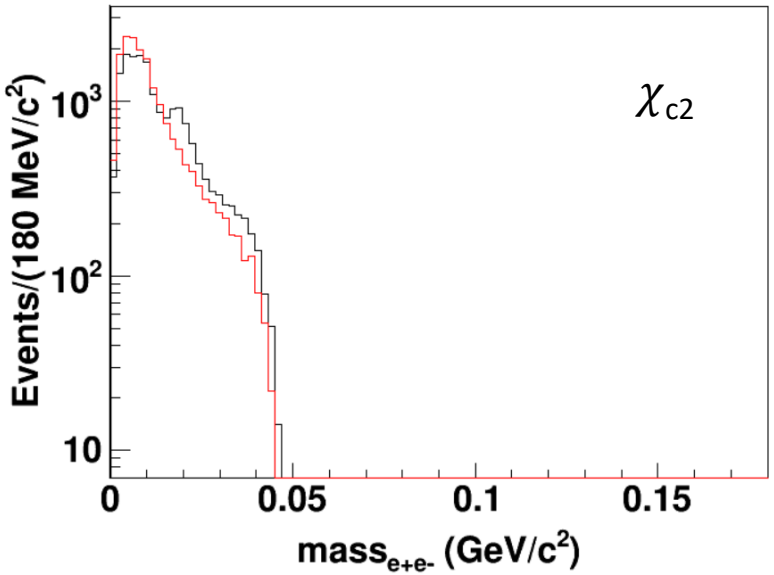
Branching fraction of $\psi(2S) \rightarrow e^+e^-\chi_{cJ}$

	Total Signal MC	After selection	Efficiency	Data yieds	BF (10^{-3})	Previous Work (10^{-4})
$\psi(2S) \rightarrow e^+e^-\chi_{c0}$	1690K	123974	7.34%	34052 ± 403	10.35 ± 0.12	$11.7 \pm 2.5 \pm 1.0$
$\psi(2S) \rightarrow e^+e^-\chi_{c1}$	150000	8305	5.54%	19257 ± 221	7.76 ± 0.12	$8.6 \pm 0.3 \pm 0.6$
$\psi(2S) \rightarrow e^+e^-\chi_{c2}$	150000	3442	2.29%	7449 ± 161	7.23 ± 0.16	$6.9 \pm 0.5 \pm 0.6$

Invariant mass e^+e^- pair







Next To Do

1. Systematic Uncertainties
   Including: Tracking, PID, ψ(2S) number, Rxy cut,
   Angle of e^+ with e^- cut， $M_{\gamma e+e-}$ cut , Rec_mass fit,
   Signal MC modeling
2. Optimise the Rec_mass fit

3. Further check the peak background

4. Switch to Ecms = 4.178 GeV, Searching for the decay of
   $e^+e^- \rightarrow e^+ e^-$ X(3872) @Ecms = 4.178 GeV

Thanks for Your Attention *!*

Angle distribution of e^+e^- pair